THE ENGINEERING REVIEW.

Edited by
C. EDGAR ALLEN.

Vol. XII. MAY, 1905. No. 5. (New Series.)

Oxy-hydrogen Welding.

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The union of metals is a problem which the engineer often has to face, and which may present considerable difficulties. For heavy work in iron and steel rivetting, with all its defects, stands alone; but for light work, joining light sheets, making small articles, and in many other cases, rivetting is unsuitable, and some other method must be found. The alternative is usually one of the many forms of soldering or brazing. These processes consist essentially in the union of the metallic surfaces by fusing between them a metal or alloy more fusible than the metals themselves, and which will alloy with them so as to make a more or less sound joint. This method is faulty in many ways, though often satisfactory enough, and is sometimes quite useless. The solder being of quite different composition—either in the nature of its constituents, or in the proportions in which they are present—from the metals which it unites, introduces a lack of homogeneity, which is always a source of weakness, especially when, as is usually the case, the solder itself is crystalline and weak.

Then, again, in presence of corrosive liquids—and most liquids are more or less corrosive—galvanic action is set up between the metal and the solder, leading to the rapid corrosion of the one or the other, usually the solder. All are familiar with the rapidity with which soldered joints give way in contact with liquids, whether it be in the humble tin saucepan or the brazed copper pipe.

In certain cases metals can be united without the aid of any solder. This is the case with malleable iron or mild steel, which become plastic at a red heat, so that the surfaces can be hammered or pressed into contact, and thus become firmly welded. Ordinary welding is, however, limited to cases in which it is possible to heat the pieces to be united to a white heat in a forge or other fire, and very often this is impracticable.

Welding, however, represents the ideal method of uniting pieces of metal,

because, no foreign solder being used, much less heterogeneity is introduced, though it by no means follows that, even in this case, the metal is perfectly homogeneous. In some cases, where ordinary welding is impossible, surfaces may be united by melting in between them a metal of as nearly as possible the same composition and properties as the metals themselves.

In all cases it is better to use the term welding for cases in which the surfaces to be united are heated to welding temperature, and are then hammered or pressed into contact, whilst the union of metals, either by direct melting together, or by the intervention of melted metal of the same composition, should be called melting together, or fusion-union. As, however, the term welding is usually used in the broader sense, it has been retained at the head of this article.

The union of metals by fusion-union has long been known, and, under the name of autogenous soldering, has been practised in the case of lead. In the erection of lead chambers for the manufacture of sulphuric acid, and in some other cases, where the presence of solder is inadmissible, the edges of the plates to be united are cleaned and brought together, and with or without the addition of more lead, as the case may be, and are fused together by the flame of oxygen and hydrogen, or, more usually, of oxygen and coal-gas, a perfectly sound joint being thus produced, without the intervention of any foreign metal.

Many workers have tried the extension of this method to other metals, for obviously there is no reason—on the surface, at any rate—why it should not be capable of a very wide extension, for in the oxy-hydrogen flame, with the gases in the right proportion, the temperature is far above that required for the fusion of any of the common metals; a temperature up to the melting point of platinum being obtainable. Indeed, as is well known, the flame is used commercially for the melting of that metal. The flame is clean, easy to handle, and has many advantages over electricity, which is the only other method that has been used for the fusion-union of metals.

The difficulties in the way of the commercial use of oxygen and hydrogen on the large scale were, however, so great that the oxy-hydrogen flame has never been used for this purpose, except experimentally, until quite recently. The difficulties have now been largely overcome by the invention of Prof. Garuti, of Milan, and his method is now being used on the commercial scale with great success by the Oxy-hydrogen Syndicate, whose offices are at 47, St. Enoch Square, and whose works are at Petershill Road, Glasgow.

The principal difficulty was the preparation of the gases in sufficient quantity and at a sufficiently low cost to make the process practicable. As the gases are required in equivalent proportions, the electrolysis of water at once suggests itself as the most likely means of obtaining them, as all other methods involve costly materials for the preparation of the two gases separately. It was to this problem that Prof. Garuti applied himself, and his efforts were ultimately crowned with success. The two points which had to be considered were, 1st, the cheap production of the gases, and, 2nd, perfect separation of them one from the other.

The phenomena of the decomposition of water by an electric current are well known. As the current passes the water is split up, hydrogen being evolved at the cathode and oxygen at the anode, in the proportion of two volumes of hydrogen to one volume of oxygen. Pure water, as is also well known, offers so much resistance to the passage of the current that it cannot be used alone, and its conducting power must be increased by the addition of some electrolyte, sulphuric acid being always used in laboratory experiments.

If sulphuric acid be used, the anode must be of some metal which will not be attacked by the liberated SO_4 ion. On the small scale platinum electrodes are used, but this would be far too costly for large scale work,

and it was found advisable to discard the use of sulphuric acid, and to use in place of it a solution of a caustic potash, a solution having a specific gravity of 35° Beaume being found convenient.

Whether the alkaline hydrates are actually decomposed by the current, or whether they merely act by increasing the conducting power of the solution, is a matter of no moment, since if they are decomposed the ions liberated at once set up secondary reactions, by which hydrogen and oxygen are liberated in the proportions in which they are present in water. If water be decomposed directly the reaction is

$$H_2O = 2\,H + O.$$

If caustic soda be split up the reaction will probably be $NaHO = Na + H + O$, the sodium and hydrogen being liberated at the cathode and the oxygen at the anode, but the liberated sodium will at once decompose water and liberate hydrogen, re-forming sodium hydrate thus: $Na + H_2O = Na\,H\,O + H$, so that the ultimate result will be the liberation of hydrogen and oxygen and the re-formation of sodium hydrate, so that the strength of the alkaline solution remains unchanged.

A great advantage of the use of a caustic alkaline solution is that the electrodes can be made of malleable iron or mild steel, the cheapest and most suitable metals for the purpose, since the plates can be made light and thin, and yet very rigid. Such plates can easily be obtained of any required size, and can be put sufficiently close together to reduce the resistance to a practicable amount.

The more difficult problem was the complete separation of the gases, and drawing them off from the decomposing vat in such a way as to prevent any possible admixture of air.

Under ordinary circumstances the gases will be obtained separate if the electrodes are some distance apart, but the closer they are together the more difficult is it to prevent some admixture, and in order to reduce the resistance the plates must be put as close together as possible. The use of a diaphragm of some sort was found to be essential to keep the gases apart, but the materials in general use gave too great an increase of resistance or else allowed the diffusion of the gas. The obvious qualities required were little resistance to the current and imperviousness to the gas. It must therefore either be permeable to the liquid or be itself a good conductor, and it must not be permeable to the liberated gases. Biscuit—*i.e.*, unglazed porcelain—carbon, and other substances, were tried, but were found to be unsuitable.

Garuti discovered that the difficulties could be overcome by the use of a metallic diaphragm, sheet iron being found to be suitable. This diaphragm is quite passive, and takes no part in the reaction provided, the potential difference between the plates is not more than three volts, and the current density not greater than two or three amperes per square decimetre, conditions which are always fulfilled in the commercial forms of the apparatus.

In order to secure uniformity of the electrolyte, and so to prevent irregularities in the current which might arise from variations in the concentration of the solution, a circulation of the solution was arranged. This being obtained by terminating the diaphragms a little above the bottom of the vats, but continuing them right up to the cover, and making the electrodes lower, so that the solution could flow over the top. In the apparatus as now used, the circulation of the solution has been found to be unnecessary, and has therefore been abandoned.

The decomposing vat consists of a vessel of mild steel plate (18 W.G. thick), 6 ft. long, 1 ft. 6 in. deep, and 1·5 in. wide, divided into two parts by a thin steel plate. The edges of the plates joining the vat are bent inwards, and are bolted together, thin sheets of india-rubber being put between them and the diaphragm, so as to insulate them perfectly. The diaphragm has a rectangular opening cut through it, to allow of the transference of the ions,

this opening being covered by a layer of very fine wire gauze. The plates which form the sides of the vat are also the electrodes. The water is supplied at the bottom of the vat, and the gases are drawn off at the top on each side of the diaphragm. Thirty vats are arranged in series.

In order that sufficient pressure may be obtained so that the gas may pass the necessary water seals, the vat, as will be seen from the description above, is hermetically closed, and must be capable of withstanding considerable pressure.

The dynamo used gives a potential difference between the terminals of 70 volts, and for a set of 30 vats arranged in series the fall of potential between each is a little over two volts. The amount of current flowing is 200 amperes, and the current density is therefore 22.2 amperes per square foot, or 2·39 per square decimetre.

The amount of water decomposed by one ampere of current is ·00009315 grammes, or ·33534 grammes per ampere per hour. As the current passing is 200 amperes, the amount of water decomposed will be 67·068 grammes for each pair of electrodes, or 2014·56 grammes for the entire vat per hour. As 18 grammes of water will yield 22·4 litres of hydrogen and 11·2 litres of oxygen at normal temperature and pressure, the amount of hydrogen obtained will be 2503 litres, or 88·39 cubic feet per hour, and the amount of oxygen will be just half this.

The gases are drawn off by separate pipes over each electrode, the hydrogen on one side of the vat and the oxygen on the other. The small pipes lead into larger pipes, the gases being of course kept separate, and then the gases pass through a seal of three feet of water.

The pipes carrying the two gases are brought together, and at points opposite to one another small jets are fixed from which the gas can escape, and a flame is kept burning. Should any accident take place and the gases become mixed, they would therefore ignite at this point, and the explosion would be confined to the short space of pipe between the water seals. Afterwards each gas is passed over a platinum spiral kept red-hot by means of an electric current, so that any trace of oxygen in the hydrogen or hydrogen in oxygen will be removed. The gases then pass on to gas-holders, where they are stored separately till they are required for use.

The gas is used direct from the gas-holders at a pressure of 15 inches of water. As the pressure required is so low, the gases need not be compressed, and the costly compressing machinery being dispensed with, the gas is much cheaper. If required for use away from the works, however, it may be compressed into cylinders in the usual way.

The gas is carried to the work-rooms by means of pipes. On the wall of the work-room nozzles are fixed, to which flexible pipes are attached conveying the gases to the blowpipes. These pipes may be of any convenient lengths, and in some cases work has been done at a considerable distance from the work-shop.

The blowpipe is of the ordinary mixed jet type, the gases being led into a long conical chamber, so as to mix thoroughly before leaving the jet. The point of the blowpipe is bent round for convenience, and the jet is made of brass, and varies in diameter from $\frac{1}{32}$ in. to $\frac{1}{4}$ in. The blowpipe itself is made of sheet-iron, and is therefore not costly.

For combustion the hydrogen requires half its own volume of oxygen. In practice it is not desirable to use anything like so large a quantity, the proportion of hydrogen to oxygen actually used being about 6 to 1. The reason for this is twofold. The external air supplies some oxygen for combustion, and in order that the flame may be reducing so as not to oxidise the metal, but rather to reduce any oxides that may be present, a considerable excess of hydrogen is necessary. There is therefore a considerable excess of oxygen, which may be compressed into cylinders and sold, or which may be used for other purposes.

The method of conducting the process

is so simple that but little explanation is necessary. Take a simple case, such as the manufacture of a small sheet-iron water cistern. As usual, a net is cut so that when the parts are folded into position the required form will be obtained. The edges that are to be united so as to form the corner seam are brought together, and contact is secured by fixing them by means of a clamp against the two sides of a rectangular bar, placed with the angle uppermost, the actual adjustment taking only a few seconds. The workman then runs his blowpipe along the joint till the edges are perfectly melted together. Should there be any point where the two pieces do not exactly meet, the workman holds a strip of metal of the same composition as that being used for the body of the article in the flame, and melts some into the required position exactly as one would melt sealing wax or solder.

The whole operation takes only a few minutes, and a perfect join is the result. No flux of any kind is necessary, since the high temperature and the reducing nature of the flame keep the surfaces perfectly clean, the formation of scale being impossible, and any that may previously have formed being reduced.

The above is only one example, and it will be seen that the possibilities of the process are very great.

The flame can be perfectly regulated, and is absolutely under control; sheet iron 24 W.G. thick can be joined; and in Tivoli (Italy) a 2,000 h.p. plant is being used for melting glass in crucibles in lots of 5 cwts. at a time, certainly a very wide range of applicability.

In welding or patching iron or steel no preparatory cleaning of the surface is necessary, and there is no chance of burning the metal, and, as there is no carbon present, the composition of the metal will undergo no change. Since the product of combustion is only water, no objectionable or unpleasant fumes are produced.

The possible applications of the process are very numerous, indeed almost numberless. Not only can thin sheets or plates be united, but any article which could be made of tin plate by soldering can equally well be made by this process without the aid of solder. Pipes and tubes can be readily made from sheet metal, and cylinders of sheet steel for holding gases under pressure have been manufactured quite satisfactorily. Tramway rails can be welded, and, in fact, any surfaces of iron or steel united. Nor is the process confined to the union of similar metals; copper or brass can be "welded" to one another, or to iron or steel, perfectly sound joints being produced in either case. Patching iron or steel castings, for which electric welding is so often used, can be done equally well by this process.

At present the process is in its infancy, but quite enough has been done to show some of its possibilities, and as it becomes further known, there is no doubt but that many other applications will be found for it.

Two important questions will be asked: (1) Is the joint made in this way strong, as strong say as an ordinary welded joint? and (2) What is the cost of working the process?

In answer to the first question it may be stated that the joint is perfectly sound, and is as strong as an ordinary welded joint, and in some respects stronger. It must be remembered that in ordinary welding the heating extends a long way from the actual weld, and that this often induces a change in structure, producing a very serious weakening of the metal, so that when the piece is tested it does not usually break at the weld, not because the weld is strong, but because the metal on each side of it has been seriously reduced in strength. Before such tests can be of much value the metal must be carefully annealed, so as to remove the stresses which have been set up. This treatment is necessary or at least advisable when large articles are welded, but in ordinary cases the heating is so local that no stresses are set up beyond the actual weld. Careful annealing will, however, in no case do any harm, and may somewhat increase the strength of the weld. In the case

of cast iron the weld is always the strongest part, and it is always desirable to anneal, otherwise the weld will stand perfectly, but a crack may develop elsewhere.

The following tests were made by Mr. W. Jack on ordinary steel plates of varying thickness. The welding was done by the oxy-hydrogen process from one side of the plates only. The plates were cut in the centre, and the surfaces were merely "butted" together, as they had left the shears without any preparation. The thickest plate was probably not properly welded through its entire thickness, and it is always desirable in the case of plates more than one-eighth inch in thickness to bevel off one edge to make sure of a perfect weld right through, or else to weld from both sides, and when practicable it is advisable to heat the article in a forge fire and hammer lightly where the weld has been made. All the lighter plates stood perfectly, showing that only care and experience is necessary for perfect work. Each test piece was 12 inches long overall, and 8 inches in the middle of the bar was cut down to 1½ inches wide.

No. of Test.	Thickness.	Description.	Breaking Stress.		Elongation.	Position of Fracture.
			Tons.	Cwts.		
1	¼ in.	Welded	9	7	5 per cent.	At weld.
1A	¼ in.	Plain	12	0	18 ,,	,, centre.
2	$\frac{5}{32}$ in.	Welded	8	0	13 ,,	,, weld.
2A	$\frac{5}{32}$ in.	Plain	7	4	17 ,,	,, centre.
3	⅛ in.	Welded	7	6	15 ,,	1½ ins. from weld.
3A	⅛ in.	Plain	7	7	14 ,,	¾ ins. from neck.
4	$\frac{3}{16}$ in.	Welded	4	1	14 ,,	1½ ins. from neck.
4A	$\frac{3}{16}$ in.	Plain	4	2	9 ,,	Neck.
5	$\frac{1}{32}$ in.	Welded	2	7	9 ,,	Neck.
5A	$\frac{1}{32}$ in.	Plain	2	9	14 ,,	Near centre.

The cost of the process is mainly the cost of the electric energy, and this will of course vary with the cost at which energy can be obtained, and this if a public supply be used will vary from 1*d*. to 3½*d*. per unit or thereabouts. Taking first the chemical decomposition, it will not be difficult to see what amount of energy will be required. The breaking up of nine grammes of water so as to liberate one gramme of hydrogen and 8 grammes of oxygen will absorb about 34,180 units of heat (gramme calories), which will be equal to 34,180 × 4·2 = 143,556 joules, or 144,566 × ·7,373 = 105,843·8 foot-lbs., so that to decompose that amount of water per minute would require 3·21 h.p. As a gramme of hydrogen occupies 11·2 litres, the energy required per cubic foot of hydrogen per minute would be just over 8 h.p., or if that amount of hydrogen be liberated per hour it would require ·135 h.p., or almost exactly one-tenth of a kilowatt hour, or unit.

It need hardly be remarked that a larger amount of energy than this will be required in practice. To return to the case already given, it was found that 88·4 cubic feet of hydrogen were evolved per hour by a current of 200 amperes at 70 volts, or 14,000 watts, which is equal to about 158 watts, or ·158 B. T. units per cubic foot, or ·212 h.p. Taking the cost of current at 1½*d*. per unit, which would be a fair average price, this would be ·237*d*. per cubic foot, or 19*s*. 9*d*. per 1,000 cubic feet of hydrogen, and 500 cubic feet of oxygen.

The London Underground Tramway.

By OUR SPECIAL REPRESENTATIVE.

As the first example in this country of a shallow underground tramway, the line now in course of construction between Holborn and the Strand possesses much interest to engineers and others who are concerned with the question of traffic facilities in large cities, and especially in the metropolis. As most of our readers are aware, this project is being executed in conjunction with the formation of the new avenue designated in advance by the good Saxon name of Kingsway.

More than sixty years ago it was generally realised how necessary and desirable was the provision of a main highway between Holborn and the Strand, not only for local traffic, but as a step towards the creation of a main artery connecting the northern and southern districts of the metropolis and opening up a direct way for traffic in place of the circuitous routes offered by streets converging at Charing Cross on one hand and in the centre of the City on the other.

To discuss the long-protracted controversies that have occurred in connection with the proposed thoroughfare is quite beyond the purview of the present article. It will suffice to say that the scheme was finally approved by Parliament in the year 1899. Since then its execution has been delayed by circumstances which the London County Council can best explain. These circumstances arose entirely out of the economic policy of the Council, and had no connection with the work of the engineering department.

As will be seen by reference to Fig. 2, the chief feature of the project is the construction of a wide avenue starting almost perpendicular to High Holborn, continuing thence across Great Queen Street to a point opposite St. Mary-le-Strand Church, and entering the Strand by the two horns of a crescent, one debouching close to St. Clement Danes Church, and the other at Wellington Street. The width of the new highways is 100 ft., and at the centre of the crescent ample space is provided to facilitate the marshalling of traffic. Passing through one of the least sanitary regions of the metropolis, the new avenue will effect a marked reform from the hygienic point of view, and when the bordering land, as well as that cleared in the Strand itself, has been occupied by new and handsome buildings, the result will constitute the most noteworthy street improvement of the present era.

Being convinced, by the report received from a deputation sent to study the means of street locomotion adopted in the United States, of the advantages presented by shallow subways for tramway services, the County Council wisely decided to seize the opportunity of

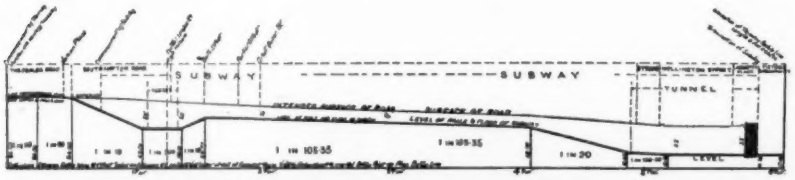


FIG. 1.—LONGITUDINAL SECTION OF THE UNDERGROUND TRAMWAY.

constructing concurrently with the new street, and as near to the surface as possible, an underground tramway track to connect the northern tramway system with the lines on the southern side of the Thames. At the same time it was determined to form suitable subways on either side of the main tunnel for the accommodation of water, gas, and other pipes, and of electricity supply, telegraph, and telephone cables, and other conduits. Further, the scheme included the formation of vaults on the outer side of the pipe subways. The objects of these vaults are to afford increased accommodation in the buildings to be erected on either side of the new avenue and to provide convenient means for the connection of house service conduits of various kinds.

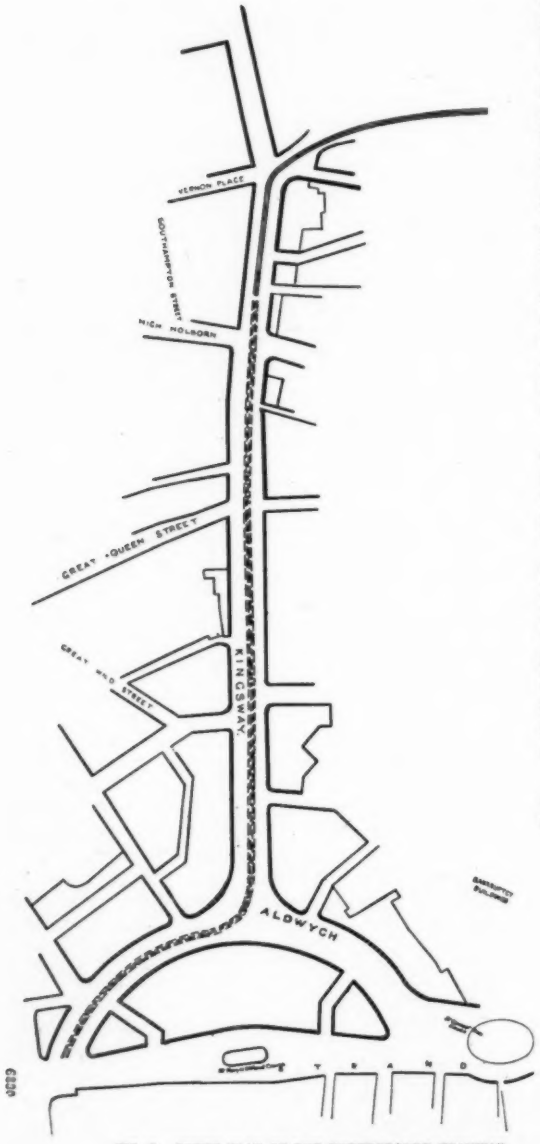


FIG. 2.—ROUTE PLAN OF THE UNDERGROUND TRAMWAY.

So far as the new road is concerned the realisation of a main highway north and south will be secured. Vehicles crossing the Thames by way of Waterloo Bridge will be able to proceed straight to North London through Southampton Row. Traffic passing southwards through Kingsway will have equal facilities for reaching the southern regions, as well as the alternative of joining the streams of vehicles travelling east or west along the Strand.

The tramway part of the scheme originally provided for the construction of a route starting from the existing lines at Theobald's Road, diving below the surface in Southampton Row, passing below Kingsway and Aldwych, thence proceeding beneath the Strand and Wellington Street, and emerging at the Victoria Embankment. Thence lines were to be carried across the river by way of Westminster Bridge to effect

a junction between the northern and southern tramway systems.

Fig. 1 is a longitudinal section of the proposed line from Theobald's Road to the Embankment. This drawing gives the levels and gradients of the road surfaces and the tramway lines, and upon it are indicated also the names of the chief streets crossed by the new thoroughfare.

Fig. 2 is a general plan of the new thoroughfares showing the underground tramway in broken lines, and the temporary terminus at the junction of Aldwych with the Strand. As most of our readers are aware, the London County Council was unable to obtain parliamentary sanction for the execution of the complete project, the final realisation of which will most probably not be witnessed for some years to come.

One circumstance in connection with the height of the subway deserves special mention. It is that the clear headway will not be sufficient to admit the double-decked cars upon which the London County Council have spent many thousands of pounds. Consequently, assuming the final completion of the line from Theobald's Road to the southern side of the Thames, none of the cars in use on the Westminster, Waterloo, Blackfriars, or Southwark routes could pass into the new subway, which is quite unsuitable for any but cars of special design. While the general idea of the subway is excellent, and the manner in which the engineering details have been designed is admirable, the utility of the project is seriously impaired by the limitation of height which was imposed by the Council upon their engineers.

Having now a bird's-eye view of the entire scheme, we will proceed to consider some of the more important details of that portion of the tramway which at the present time is under construction.

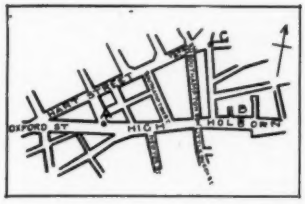


FIG. 3.—KEY PLAN OF BORINGS.

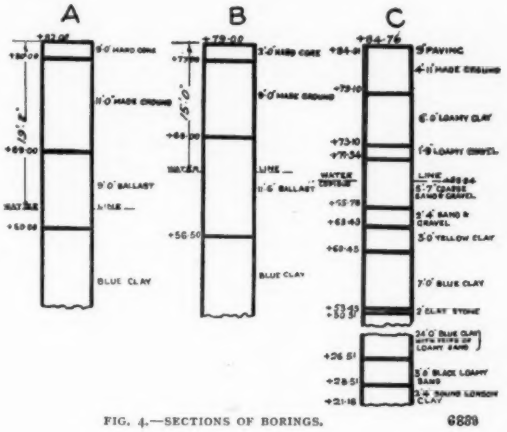


FIG. 4.—SECTIONS OF BORINGS. 6889

The formation of the subway has been attended by circumstances that have caused delay and difficulties of no mean order. Even after the acquisition of the property along the line of the intended route, the demolition of buildings involved extensive underpinning works for the purpose of preventing injury and the risk of injury to adjoining structures, many of these being of large size and in such condition that a very little movement might have resulted in considerable damage. Another series of operations, accounting for the expenditure of much time, was necessitated by the removal and rearrangement of numerous water and gas mains, service pipes, electricity cables, telegraph cables, and telephone wires.

Before the commencement of work, trial borings were made at the points *A*, *B*, and *C*, on the key plan, Fig. 3.

The results of these borings are indicated in Fig. 4, and it will be seen that between the point *C*, near where the new line starts on the street level, and the point *B*, not far from the place where it passes below High Holborn, the blue clay is within about 24 ft. below the surface. Referring to Fig. 1, we find that the lower end of the permanent way under High Holborn is 48·01 ft. above ordnance datum, and although, as shown by section *C*, Fig. 4, the clay is interspersed by veins of claystone and loamy sand, there is sufficient reason for being satisfied with the bearing power of the earth for the new work in this particular section. The borings do not afford any evidence as to the character of the subsoil between High Holborn and the Strand, but this part of the subway is founded on soil chiefly of a gravelly character. With the exception of the slope from Theobald's Road to High Holborn, the lower part of the subway for its entire length is below the water line, and in some places the whole construction is below the same level. For this reason it was necessary to take adequate precautions against the percolation of water both during and after the execution of the works.

The first sections of the subway to be undertaken were those between Vernon Place, Theobald's Road, and Great Queen Street at the northern end, and beneath the western arm of Aldwych at the southern end. Fig. 5 is a longitudinal section of the tramway from Vernon Place to Great Queen Street. Commencing with a down gradient of 1 in 10, the rail level of the slope dips below the water line 14 ft. before the line passes under the foot pavement on the northern side of High Holborn, and about 90 ft. beyond the clay is entered. The downward gradient of the tunnel under High Holborn commences at 1 in 10, and is reduced to 1 in 200, and the upward gradient on the southern side is 1 in 10, bringing the rail level above the clay near Gate Street, a little beyond which is one end of the Great Queen Street station.

In Southampton Row the permanent way is 83·76 ft. above ordnance datum, and has a foundation layer of 8 to 1 Portland cement concrete, 9 in. thick, furnished with a 2-in. surface of asphalt. The slope, commencing immediately above the crown of the horseshoe transverse gallery shown in Fig. 5, and which connects the pipe conduits on either side of the line, has a stepped foundation of 8 to 1 Portland cement concrete, with a maximum depth at each step of about 4 ft. Upon the surface of the stepped footings a $\frac{3}{4}$-in. layer of asphalt was spread before the concrete filling was deposited to form the inclined surface. This system of construction continues for a horizontal distance of about 255 ft., or 25 ft. beyond the point at which the clay formation has been entered. The entrance to the tunnel beneath Holborn is at a horizontal distance of about 180 ft. from the commencement of the incline, and at the entrance the rail level is nearly 18 ft. below the surface. On each side of the cutting is a retaining wall with a parapet rising 14 in. above the street pavement, and surmounted by iron railings. Refuge niches are provided at intervals along the retaining walls, as shown in Fig. 5.

Fig. 6 is a transverse section taken in front of the north entrance to the tunnel. This drawing shows the construction and positions of the main subway, the pipe subways, and a vault under the footpath. The retaining wall proper has a thickness of 5 ft. 6 in. at the bottom, diminishing by four steps to a thickness of 1 ft. $1\frac{1}{2}$ in. at the top. For the purpose of preventing the percolation of water into the masonry, a $\frac{3}{4}$-in. damp course of asphalt is carried down each side and across the concrete footings, which are formed of 8 to 1 Portland cement concrete. Concrete filling 2 ft. thick, mixed in the proportions of 12 to 1, is carried to the level of the first step, thus making the total thickness of the wall 7 ft. 6 in., and above the first step dry filling is employed. The dimensions of the refuges along the inner face of each retaining wall are 6 ft. 6 in. high by 3 ft. wide by 1 ft. deep. Surface water in the cutting is collected by three

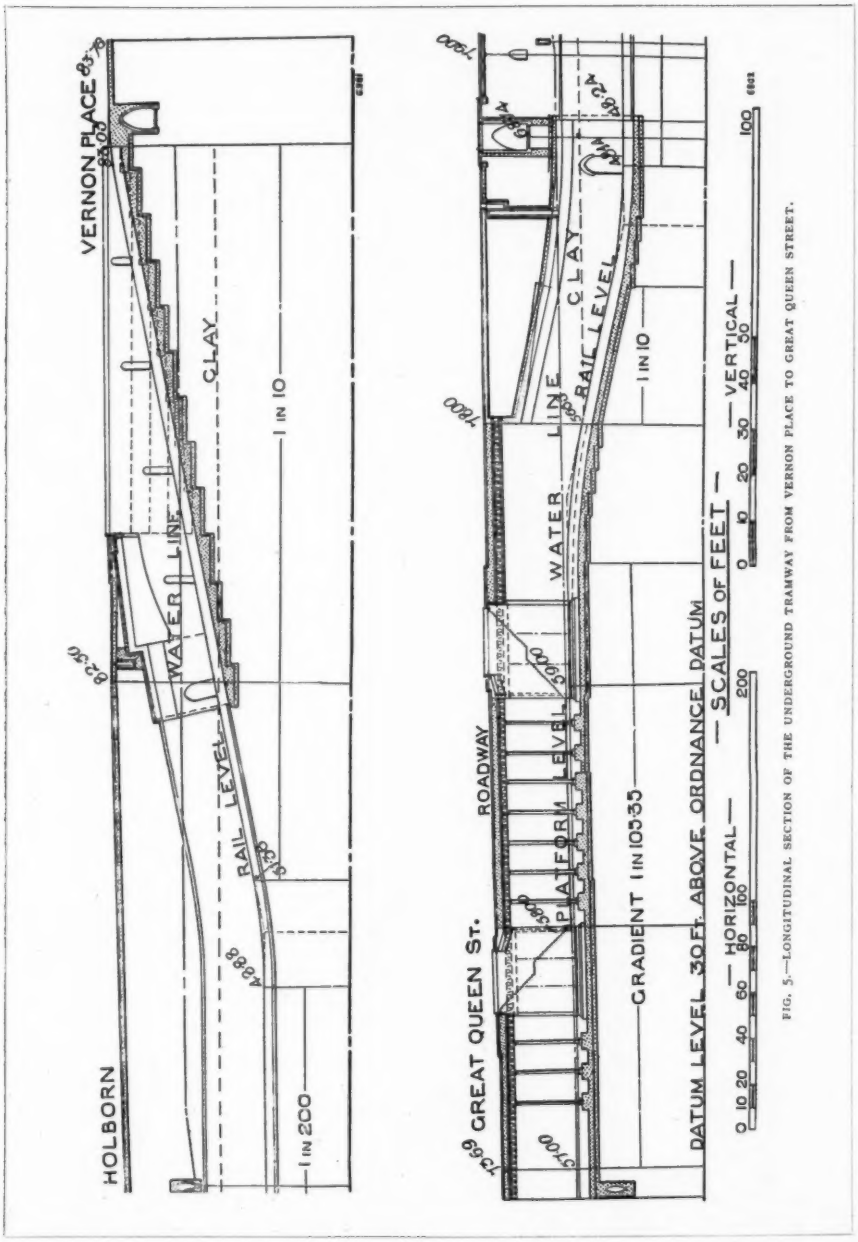


FIG. 5.—LONGITUDINAL SECTION OF THE UNDERGROUND TRAMWAY FROM VERNON PLACE TO GREAT QUEEN STREET.

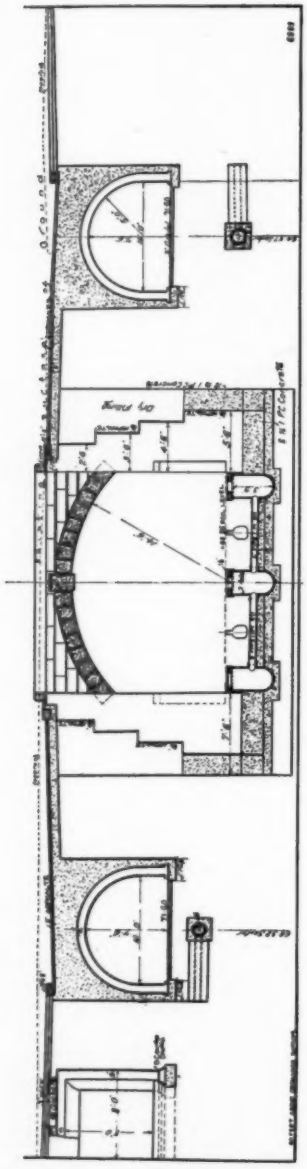


FIG. 6.—CROSS-SECTION SHOWING NORTH ENTRANCE TO THE UNDERGROUND TRAMWAY.

drains connected by 6-in. pipes, as shown in Fig. 6. That part of the work described as the entrance is an arched tunnel with a span of 20 ft., the roof consisting of five segmental arch rings of brick set in cement. The pipe subways measure 10 ft. wide at the bottom, the arched roof having a radius of 5 ft., the springing being at the height of 2 ft. above the floor, which is composed of a layer of gravel 3 in. thick. At the horizontal distance of about 45 ft. from the front the entrance tunnel divides into two separate single track subways, as represented in Fig. 7, divided by a concrete wall 5 ft. 7 in. thick faced with white glazed brick. In front of the division wall is an intercepting chamber, measuring 4 ft. by 6 ft. by 7 ft., into which surface water is delivered from the drains in the cutting. As will be observed by examination of Fig. 7, a $\frac{3}{4}$-in. damp course of asphalt is carried entirely round the sides, top, and bottom of the concrete walls and over the concrete filling above the brick arches. All these parts are of 8 to 1 concrete, the outer filling and the foundation slab being of 12 to 1 concrete. The space between the concrete cover of the tunnels and the concrete foundation of the roadway is occupied with dry filling. Fig. 7 is a cross section at the north end of the cast-iron tubular tunnels, and shows the position of the cast-iron tubes through which the tramway lines are carried beneath High Holborn. The double track tunnel is provided with refuge niches similar to those in the retaining walls of the open cutting, and between the two single track tunnels there is an opening which measures 8 ft. high by 7 ft. wide. All these tunnels were constructed in cut and cover.

Referring back to Fig. 5, we see that the 1 in 10 gradient continues for a horizontal distance of 75 ft. beyond the commencement of the tubes, when it enters the concave curve of 500 ft. radius, proceeding with a gradient of 1 in 200 to the south side of the street, and afterwards rising with a concave curve of 500 ft. radius, a gradient of 1 in 10, and a convex curve of 500 ft. radius

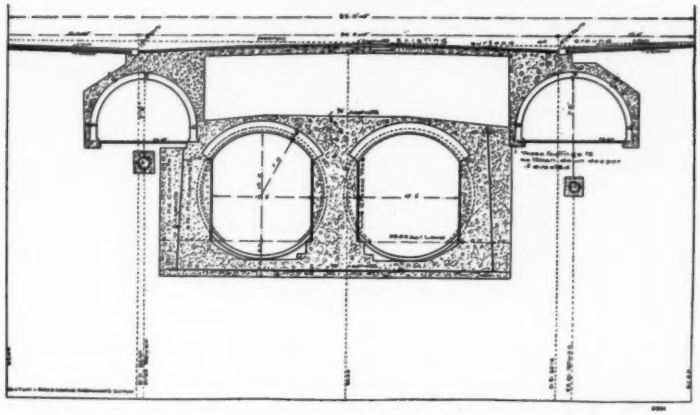
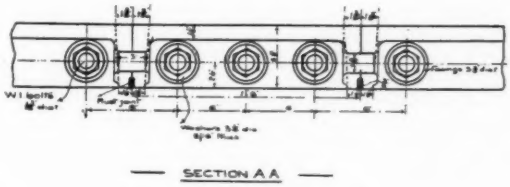


FIG. 7.—CROSS-SECTION AT THE NORTH END OF CAST-IRON TUBES BENEATH HOLBORN.

to the level of Great Queen Street station. The depth of the subway below High Holborn was governed by the necessity for avoiding the existing sewer shown at the middle of Fig. 5. The rail level at the lowest point is about 32 ft. from the surface of the roadway. The headings were driven by shields resembling those used in the construction of the Central London Railway,



SECTION A A

FIG. 9.—DETAIL OF TUBE JOINTS.

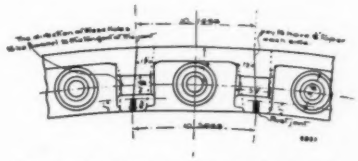


FIG. 10. - DETAIL OF KEY AT CROWN OF TUBE.

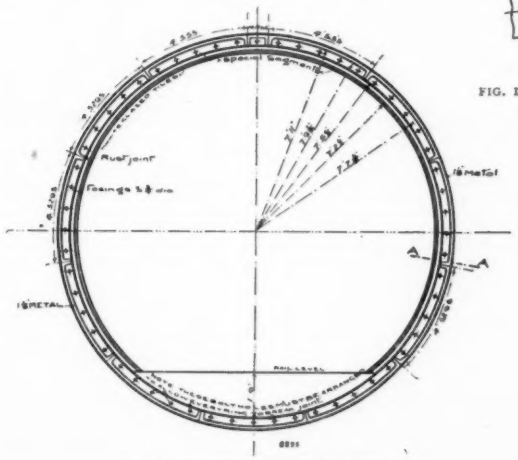


FIG. 8.—SECTION OF CAST-IRON TUBE.

the hydraulic rams being operated by water supplied from pumps driven by two portable engines. Operations were commenced at the southern side of Holborn, the abutment to afford purchase for working the shields being furnished by a block of concrete about 5 ft. thick and pierced by circular openings finished with brick arch rings.

As may be seen by Figs. 4 and 5, the material through

which the tubes pass consists of clay for about three-fourths of the height and for the remaining distance of ballast. At the northern end, however, the tubes emerge almost entirely from the clay.

The material excavated was hoisted by means of cranes, loaded into carts, and carried away through the streets. The same course was adopted, and is still being followed, on other parts of the works. Considering the fact that the Council have been in full possession of the land throughout the length of the new thoroughfare, it is surprising that so costly and inconvenient a method of removing material should have been permitted. If the construction of the new tramway had been entrusted to a business firm instead of to the Works Department of the Council, it is highly probable that all debris would have been transported by a light tramway extending from Holborn to the Strand, and continued through a small heading to the Victoria Embankment so as to permit all the excavated material to be taken away by barge. We are surprised that the Council did not adopt some such expedient, for, in addition to saving money, it would have relieved the streets of much unnecessary traffic of particularly obstructive character.

Fig. 8 is a general cross-section of the cast-iron tube lining, which has an interior diameter of 14 ft. 11 in. and an exterior diameter of 15 ft. 10 in. Each tube section is built up of nine segments, with an external periphery of about 4 ft. 5·295 in. by 20 in. wide, two special segments 4 ft. 5·55 in. long by 20 in. wide, and one key segment at the crown 10·1466 in. long by 20 in. wide, with a taper of $\frac{1}{8}$ in. on each side. The division of the ring into segments of three different sizes seems to be quite unnecessary, and has involved expense and trouble that could have been very well avoided.

All the butting surfaces of the joints were machined to gauge and fitted together with red lead, but a 1-in. recess was left inside for the making of an ordinary rust joint between each of the segments. The thickness of metal in the outer plate of all the segments is $1\frac{1}{8}$ in., and of the internal flanges $4\frac{3}{8}$ in., making an overall depth of $5\frac{1}{2}$ in. The segments of each ring are connected together by bolts of $1\frac{3}{8}$ in. diameter, and beneath the nuts at each end of which are a $3\frac{1}{4}$ in. by $\frac{5}{16}$ in. iron washer and a lead washer intended to squeeze into the threads as the bolts were tightened up. The separate rings of segments are connected by bolts of $1\frac{3}{8}$ in. diameter, the holes for which were arranged to cause every ring to break joint. As in the case of the horizontal joints, the surfaces were machined to gauge and fitted together with red lead and internal rust joints, as before described. Figs. 9 and 10 are to

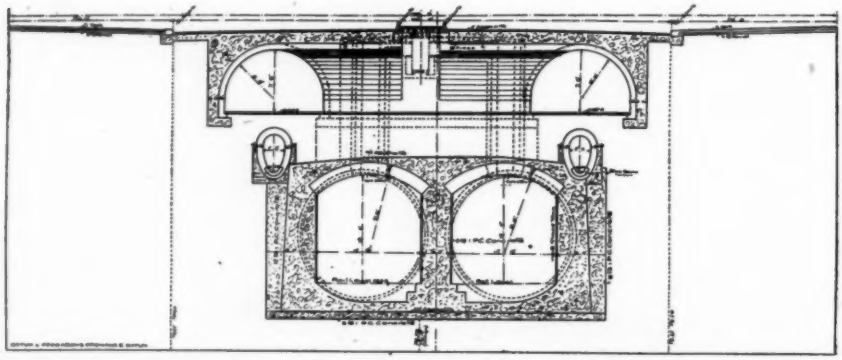


FIG. 11.—CROSS-SECTION AT THE SOUTH END OF CAST IRON TUBES BENEATH HOLBORN.

an enlarged scale and make clear the details of the tube joints.

A 1½-in. grouting hole was provided in each segment closed by a plug with a grummet and wrought-iron washer, each of the latter being ¼ in. thick. Blue lias lime grout was injected through the holes under pressure after completion of each tube ring. As shown in Fig. 8, the interior surface of each tube is lined with white glazed tiles.

Fig. 11 is a cross-section of the subways taken at the south junction of the cast-iron tubes with the brick and concrete single-track tunnels; the position of this section in Fig. 5 is indicated by the vertical dimension 48·24 ft., which is the height of the rail level above ordnance datum. The drawing shows the transverse gallery connecting the pipe subways, a cross-section of the gallery being given in Fig. 5. No detailed reference need be made to Fig. 8, as the construction is generally similar to that already described when dealing with Fig. 7.

From the southern end of the cast-iron tubes two concrete and brick-arched tunnels extend with a down gradient of 1 in 200 for a horizontal length of 20 ft., an upward curve of 500 ft. radius for a horizontal length of 52 ft., and an upward gradient of 1 in 10 for a horizontal length of 60 ft. Thence the work is continued as a subway with a steel troughing flat roof, and a central wall of brickwork 3 ft. 6 in. thick, to a point almost immediately below the beginning of the northern stairway leading to the Great Queen Street station. This portion begins with an upward convex curve of 500 ft. radius and a downward gradient of 1 in 105·35 into the station. Both the last-mentioned sections of the subway were executed in cut and cover, and it will be observed from Fig. 5 that the foundation is stepped for the greater part of the distance in the manner already described in connection with the northern end of the subway. A ventilating shaft is provided near the commencement of Kingsway, and an entrance to the pipe subways (see Fig. 5).

The single track tunnels at the southern side of Holborn are of similar construction to those at the northern side. The outer walls are of 8 to 1 Portland cement concrete surrounded by a ¾-in. asphalt damp course; the centre wall, as already mentioned, is of brick, the foundation slab and outer filling of 12 to 1 concrete, and the foundations for the egg-shaped sewers of 7 to 1 concrete. The retaining walls, centre wall, and the side walls of the pipe subways are finished with York bed stones 6 in. thick, upon which is placed the 12-in. steel troughing which forms the roof of the entire construction. Here, and in other places, the troughing is coated with pitch after erection, being then filled with concrete, which is protected by a damp course of asphalt. Over the roofing is a bed of 8 to 1 concrete, with a maximum depth of 3 ft., and on this is laid a 2 in. surface of asphalt paving. The interior wall surfaces are lined throughout with white glazed tiles.

Great Queen Street station commences at the end of the flat-roofed section, and to provide sufficient space for the platform the side walls of the subway diverge to give the width of 30 ft. from side to side. Fig. 12 is a longitudinal section through the station, which has an island platform 100 ft. long by 12 ft. wide, paved with York stone and edged in blue brick. Access is given by two staircases, each 6 ft. wide, having two flights of sixteen steps with 12-in. treads and a 6-in. rise. Half-way up each staircase there is a landing 6 ft. square. The steps and the landings are of York stone, and are fitted with Mason's patent treads.

Fig. 13 is a cross section through the line *E F* at the southern end of the station, where the details are identical with those at the northern end. From this drawing it will be seen that the steel troughing extends from the outer wall of each subway across the side walls of the station to the walls supporting the staircase.

Fig. 14 is a cross-section at the line *C D*, which passes through the centre of the station. In this case the steel troughing extends from the outer wall

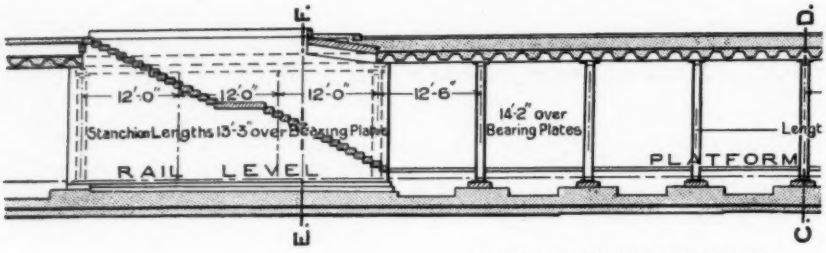


FIG. 12.—GREAT QUEEN STREET STATION.

of each pipe subway to the central stanchion, which is one of nine fixed in the longitudinal row along the centre of the platform (see Fig. 12).

At the right hand of Figs. 13 and 14 is shown a vault of the kind previously mentioned as being provided for buildings to be erected along the route of the new subway. Fig. 15 gives details of the stanchions, girders, and steel troughing. The stanchions are spaced 13 ft. apart, centre to centre, the length over the bearing plates being 14 ft. 2 in. The latter stand on granite blocks, each 2 ft. 9 in. square by 9 in. thick, and through them pass holding-down bolts having foundation plates 12 in. square by $\frac{3}{4}$ in. thick. The stanchions consist of 12 in. by 6 in. rolled steel I-bars, to the flanges of which are riveted $\frac{1}{2}$-in. steel plates 9 in. wide with $\frac{1}{2}$-in. gusset plates, and $6\frac{1}{2}$ in. by $4\frac{1}{2}$ in. by $\frac{1}{2}$ in. angle bars at the bottom, forming a base 2 ft. square. At the top of the stanchion $6\frac{1}{2}$ in. by $3\frac{1}{2}$ in. by $\frac{1}{2}$ in. angle bars form a support for the $\frac{3}{4}$-in. bearing plate, which measures 1 ft. 9 in. by $12\frac{1}{2}$ in. At the top of the bearing plates a built-up steel girder runs longitudinally from end to end of the station. This girder is composed of two 15 in. by 4 in. by 4 in. channel bars, spaced $2\frac{1}{2}$ in. apart, and two $\frac{1}{2}$-in. plates 12 in. wide. Upon it the ends of the steel troughing are supported, as shown in the section *E F* (see Fig. 15).

Beyond the southern staircase the stanchions and steel trough roofing are continued for a short distance along the line (see Fig. 5), and the gradient of 1 in 105·35 continues to the end of Kingsway. Fig. 16 is a cross section close to the vertical dimension 57·00 ft. at the left hand of Fig. 5. This drawing contains some useful and interesting particulars relative to the general construction of the subways, sewers, and pavement vaults, and shows the

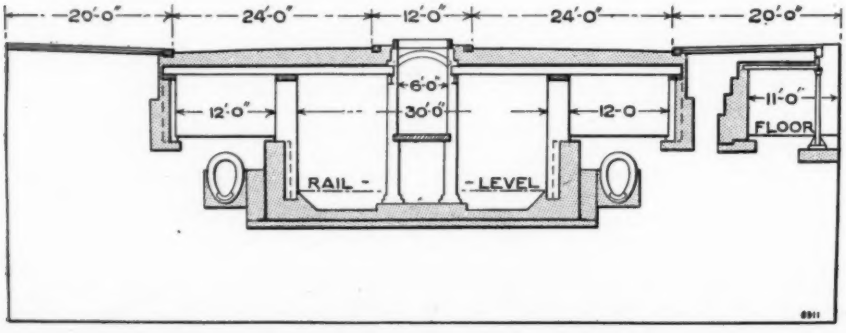
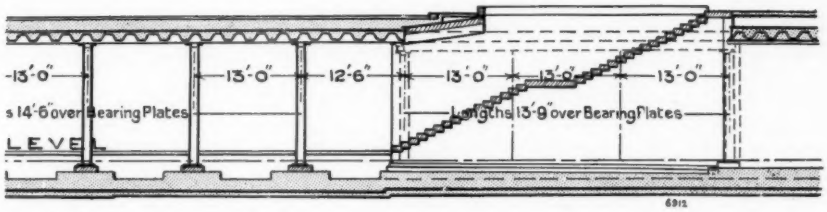


FIG. 13.—GREAT QUEEN STREET STATION: CROSS-SECTON OF E F.



LONGITUDINAL SECTION.

arrangement of drain and service pipe connections.

Comparatively little progress has been made with the middle section of the subway extending, with a downward gradient of 1 in 105·35, from Great Queen Street station to the end of Kingsway, and as the design of the work and methods of construction are generally similar to those illustrated by Fig. 16, it is not necessary to occupy the time of our readers by detailed description.

At the junction of Kingsway and Aldwych a passenger station generally similar to that at Great Queen Street is being built, and beyond this station the rail level enters a downward gradient of 1 in 20, which continues to the point below that at which the western horn of the crescent passes into the Strand. The gradient is then reduced to 1 in 108·3, the work included in the present contract terminating 40 ft. beyond.

After leaving the Kingsway-Aldwych station, the tracks enter the curve of 573 ft. radius which sweeps round below the western horn of Aldwych. At the beginning of this curve, where the top of the subway is near the surface, the roof is of steel troughing, which gives place as the depth increases to arched roof construction, supported by side walls and a central wall in concrete.

Great care was necessary in the execution of the curve, not only in fitting the troughing, but in the erection of the centring for the brickwork, and the construction of the brickwork itself. The centring ribs, which were only 3 ft. apart, had to be set separately, and the lagging to be bent to the form required to ensure accuracy. Moreover, the glazed bricks of the facing were trimmed and ground on the inside curve so as to secure close joints.

Near the end of the 1 in 20 gradient the tunnels open out to a bell-mouthed form, as shown in Fig. 17. The end of

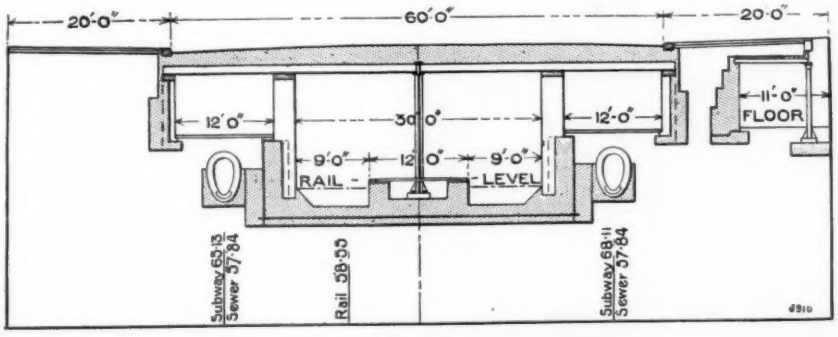


FIG. 14.—GREAT QUEEN STREET STATION: CROSS-SECTION ON C D.

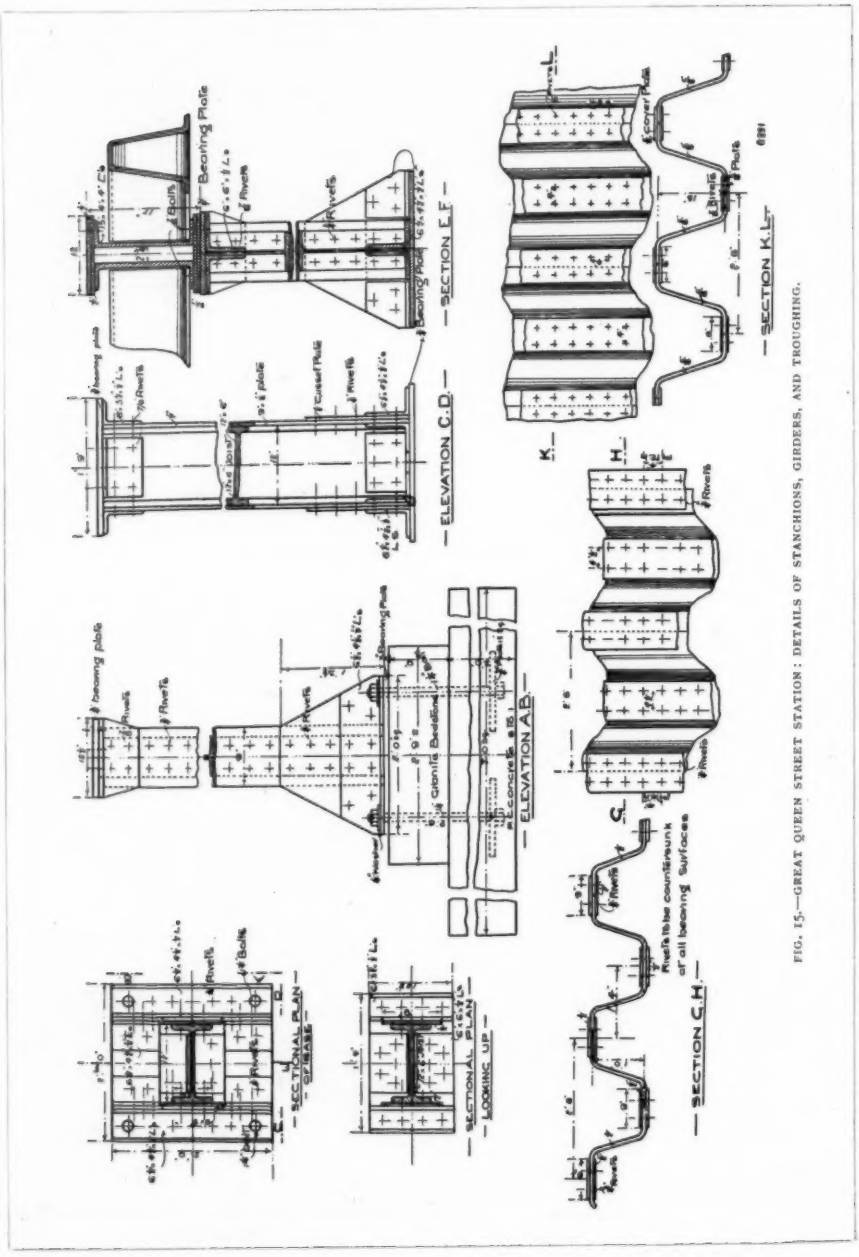


FIG. 15.—GREAT QUEEN STREET STATION: DETAILS OF STANCHIONS, GIRDERS, AND TROUGHING.

the bell-mouth is partly closed by a vertical wall of concrete, in the lower portion of which is the commencement of two tunnels, 38 ft. in length, having vertical side walls and arched roofs consisting of five brick rings at the haunches, and four rings at the crowns, all the brickwork being set in cement. These tunnels are also bell-mouthed, as indicated in Fig. 18, and in the wall at the end are two circular openings, each having a brick arch ring consisting of four courses of blue brick set in cement. The arch rings are secured to the concrete abutment beyond by a series of Lewis bolts, spaced 1 ft. 10·04 in. apart, as shown in Fig. 18, which is a cross section on the line *J K* in Fig. 17.

Beyond the last-mentioned circular arch rings it is proposed, as soon as sanction can be obtained, to carry the subway in cast-iron tubes under Wellington Street and Lancaster Place to the Victoria Embankment. In the meantime the termination of the work authorised is marked by the concrete abutment behind the two arch rings.

Having considered the constructive details of the two portions of the subway on which substantial progress has been made, it may now be useful to append some general information relative to the work as a whole.

At the outset it may be observed that the creation of an underground route close to the surface of the new highway is a most desirable innovation, obviating the delays caused by lift journeys down to and up from low-level electric railways and presenting none of the difficulties in the way of ventilation that militate so much against the desirability of all the tubular lines hitherto constructed. Much

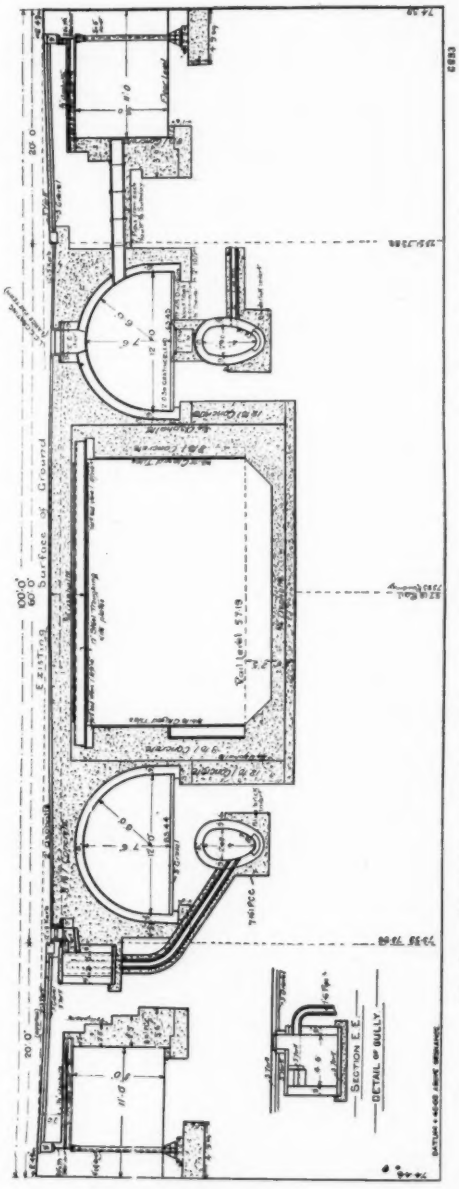


FIG. 16.—CROSS-SECTION AT GREAT QUEEN STREET OF SUBWAYS, SEWERS, DRAINS, VAULTS, AND PIPE CONNECTIONS.

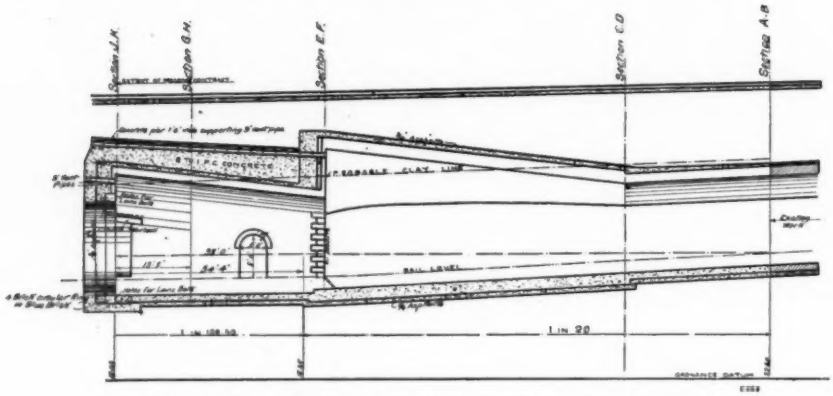


FIG. 17.—LONGITUDINAL SECTION OF THE UNDERGROUND TRAMWAY AT THE ALDWYCH END.

advantage also will follow the facilities afforded for the reception of pipes and other conduits, and for the connection of house services without disturbance of road and foot pavements.

With regard to actual construction, we may remark that as the subways are so near the surface, and in view of the unstable nature of the upper layer of made ground, extending in places to a depth of fully 5 ft., it has been necessary in many parts of the line to encase the main and subsidiary subways in concrete, so as to ensure adequate strength. The illustrations already given show that the roofing of the subway varies in design, being of steel troughing where the surface is closely approached, and of arched form where the crown loads are greater.

The general width of the double track portions of the subway is from 20 ft. to 23 ft., and of the single track sections from 13 ft. to 17 ft., the height being nowhere less than 12 ft. 11 in. above the rail level. The bottom of the subway is of concrete throughout the entire length of the line, the average thickness being 2 ft., and an asphalt damp course is invariably laid in the concrete. The rail level is 2 ft. above the bottom of the subway.

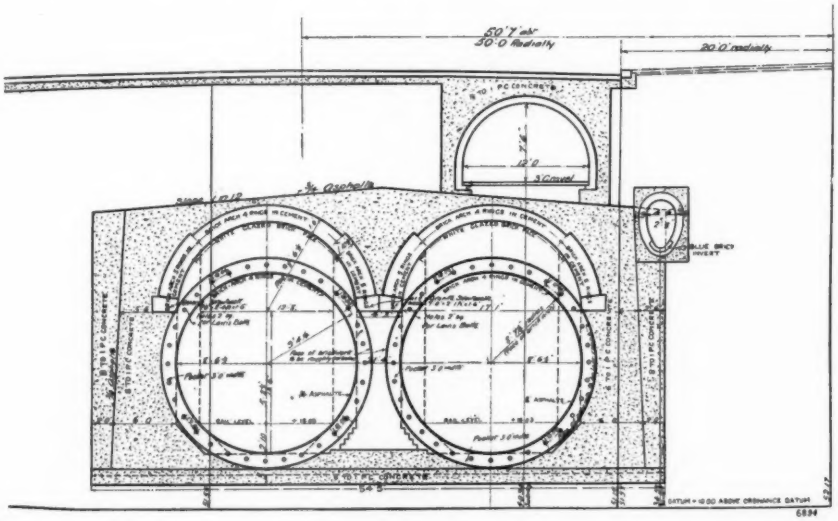
As a general rule, the pipe subways have a cross section similar to that shown in Fig. 6, the roof consisting of brick arch rings set in cement. In some parts of the work the side walls are carried up vertically to receive the ends of steel troughing which forms a continuous roof for the main and auxiliary subways, as in Figs. 13 and 14. The flooring consists of a 3-in. layer of gravel in every case. The height of the pipe subways is 7 ft. 6 in., and the width varies between 10 ft. and 12 ft. Ventilation shafts are provided at intervals, these shafts being of brick finished with 24 in. diameter gratings at the pavement level. As the gratings are removable, the ventilation shafts can be used for the passage of pipes and fittings required in the subways. One of these shafts is shown above the right-hand subway in Fig. 16. Drainage is provided for by catch-pits measuring 2 ft. square by 1 ft. 6 in. deep, built of brick upon a 3-in. York stone slab, or formed in concrete as shown in Fig. 16. The catch-pits are fitted with gratings and 6-in. trapped connections to the sewers. Some of the larger water and gas mains will be laid along the bottom of the subways, and the smaller conduits will be carried on horizontal bars suspended at one end by eye bars fixed near the crown of the arch, and at the other end by eyes fixed at the springings. The horizontal bars are perpendicular to the axis of the subways, and are spaced at intervals of 6 ft. apart. Sufficient space is left

between the bars projecting from each side to afford a clear passage along the centre of the subway.

As may be seen by comparison of Figs. 6, 7, 8, 11, 13, 14, 16, and 18, the relative positions of the tram and pipe subways vary at different parts of the line. In Fig. 6 the side subways are quite separate from the main tunnel; in Fig. 7 they adjoin the single-track tunnels; in Fig. 8 they are entirely above the tramway; in Figs. 11, 13, 14, and 16 they are close to the side walls of the central subway; and in Fig. 18 one pipe subway is shown upon the top of the bell-mouthed end of the tunnel beneath the Strand.

Similarly, the pavement vaults are at varying distances from the pipe subways. Where built separately, as in Fig. 16, the vaults have front walls of concrete 3 ft. 6 in. thick at the base, diminishing by steps to 1 ft. 3 in. immediately below the surface. At the back is a 20 in. by 7½ in. rolled steel girder supported at intervals by stanchions consisting of 8 in. by 5 in. rolled steel joists with gusset plates and angles forming the base, and angles supporting the top bearing plate. The stanchions are fixed upon 6-in. granite bedstones, below which is the concrete foundation. The roofing consists of concrete slabs or brick arches supported by 6 in. by 4½ in. rolled steel joists, and a ⅝-in. asphalt damp course is laid over all. The average dimensions of the vaults are 11 ft. from front to back and 8 ft. high. It may be mentioned that the girder at the back of the vaults is intended to support the front walls of the buildings to be erected along the new thoroughfare, and it is of very ample proportions, so as to permit the spacing of the stanchions to be increased where such a course may be desirable in the interests of tenants.

At present very little information is available as to the character of the new buildings that will be built during and after the completion of Kingsway and Aldwych. Much of the old property still remains to be demolished, and even on sites that have been cleared there is comparatively little evidence of activity in the way of building. Consequently the design of the vaults has been far



SECTION J.K.

FIG. 18.—CROSS-SECTION OF THE UNDERGROUND TRAMWAY AT THE ALDWYCH END.

more massive and costly in some places than will be necessary, and at other points it may possibly prove to be inadequate for the loads to be supported. In a few cases, where the building plans were available the vault construction has been proportioned to the calculated loads, and the details are different from those typically represented by Fig. 16.

Owing to the position of the pipe subways, which are frequently near the side curbs of the roadway, the construction of special gullies has been necessitated, as illustrated in Fig. 16. This gully comprises a square chamber 4 ft. 6 in. by 2 ft. by 5 ft. deep, with 9-in. brick walls built upon a 3-in. slab of York stone and a concrete foundation. The chamber is beneath the foot pavement, and is provided with a removable cover for cleaning purposes. Communication between the grating at the curb of the roadway is afforded by means of an inclined culvert with brick sides and a York stone bottom. The detail in Fig. 16 is a section parallel to the axis of the street. The pipe connecting the chamber with the sewer is carried almost to the top of the gully, so that the latter is always nearly full.

It is extremely difficult to say what will be the net cost of the works. Including improvements to the Strand at Holywell Street, the Clare Market clearance scheme, the Shelton Street scheme, the Parker Street lodging-house, the widening of Southampton Row, and clearance of the route from Holborn to the Strand, the estimated cost amounts to the enormous sum of £6,165,078. As a set-off it is estimated that recoupments will amount to £4,201,800, and on this assumption the net cost of the works should be £1,781,878. We all know by past experience that estimates are not invariably justified by results, and that London County Council estimates rarely represent the actual expenditure. In the present case, owing to the dilatory manner in which the Council have proceeded with the acquisition of the property required and to the leisurely methods of the Works Department, rebuilding operations have been hindered to an unprecedented extent, involving enormous losses not only to the general body of ratepayers, but also to those of the parishes affected. Moreover, there seems to be little general disposition on the part of capitalists to fall in with the ideas of recoupment entertained by the Council. Bearing all these points in view, it is tolerably clear that the total cost of the improvement will be vastly in excess of the estimates made before the execution of the project was commenced.

In conclusion, the writer desires to express his acknowledgments to Mr. Maurice Fitzmaurice, the chief engineer to the London County Council, for permission to reproduce the drawings which illustrate this article, and to inspect the works in progress.

Liége and its Exhibition.

By J. WALTER PEARSE.

(Memb. French Soc. Civil Engineers.)

THE city of Liége is situated at the confluence of the Ourthe with the Meuse, in the extreme east of Belgium, near the Dutch and German frontiers. The Romans made two roads on the high ground to the north of the city, as is evidenced by the remains of houses, factories, and even iron smelting works, with the tuyeres of low furnaces; but the nucleus of the future city was a chapel built by Saint Lambert, in the year 629, on one of the small islands at the confluence of the two rivers. The marshy land was gradually reclaimed; and houses soon clustered round the chapel, which eventually gave place to a cathedral. Although this no longer exists, its site is marked by the Place Saint-Lambert, now the centre of business in the modern city, with its 170,000 inhabitants.

The growth and prosperity of Liége are intimately connected with the discovery of coal, as to which the following legend has been handed down:—A poor blacksmith, named Hullos, was bitterly lamenting his hard lot, with charcoal so dear that he could not make both ends meet, when there appeared to him an angel, in the form of an old man with white beard, who bade him cease repining, but go and gather some of the black stones he would find on the neighbouring hill-side, and use them to heat his iron. Hullos took this advice and found that the stones answered his purpose very well, so that he soon attained a certain degree of prosperity. From his name, which is perpetuated by one of the Liége streets, originated the word "houille," which is generally used to designate coal in place in the mine, in contra-distinction to "charbon" for that put to bank ready for use. In Liége, however, it is used commonly in this latter sense; and "La houille!" is to this day cried in the streets.

Practical people thus explain the above legend. Reversing the dictum of the Roman emperor, who, when some British captives were brought before him, exclaimed—"Angeli, non Angli!" they contend that the old man with white beard, who appeared to Hullos, was an Angle (Englishman), a mining engineer of the period, who thus introduced coal-mining from Tyne-side to the banks of the Meuse. However that may be, there is documentary evidence that coal was worked at Liége in 1195, thus establishing this district as the birthplace of coal-mining on the Continent. This evidence is afforded by a diary kept by the monk Regnier (1156—1230), who chronicled noteworthy passing events.

So early as 1278 the Liége miners recorded their customs and jurisprudence in written documents which are still extant. From that period, ownership of the surface also carried with it that in the underground minerals (as in Great Britain) until 1810, when the Code Napoléon reserved all minerals to the State. The French Revolution swept away the Court of Colliery "voirs-jurés," which had existed from the thirteenth century, and exercised even greater authority than the present Council of Mines. The pillar-and-stall method of working was practised by the Liége miners, who sometimes employed windmills for mine pumping.

The Liége coalfield forms part of the great carboniferous band that extends, more or less regularly and continuously, from Westphalia to the west of Great Britain, being continuous with the Wurm basin, but cut off by the mountain limestone from the main Belgian coalfield. It is chiefly situated on the left, or northern, bank of the Meuse, which flows generally from west to east up to the city of Liége, when it turns northward. The northern portion of the coalfield is regular, with seams slightly dipping toward the south; but the southern portion is characterised by very contorted measures, the seams being in many cases quite inverted, so that the geological roof becomes the actual floor. In the northern and also in part of the southern Liége suburbs, the coal crops out to the surface, being covered between the two by Meuse gravel. The northern portion is overlain by secondary, tertiary, and recent rocks; and on the south the seams are covered by the old red sandstone, the separation being effected by the great Eifel

THE WORKS OF THE SOCIÉTÉ JOHN COCKERILL, SERAING.

fault, which, extending from the Ruhr to the Pas de Calais, crops out to the right bank of the Meuse.

The southern portion of the coalfield is very fiery; but the northern is not so much troubled with fire-damp. The coal in the south is bituminous or semi-bituminous, suitable for making coke; but that in the north is non-bituminous, and even anthracitous, just the quality for continuous stoves. The method of working with complete gobbing is made obligatory, chiefly for ensuring efficient ventilation, but also for preventing underground fires and subsidence. The timbering of the workings in highly upthrown seams is very complicated, and requires great experience when the coal is friable, as it generally is at the folds of contorted seams. Three main varieties of coal are mined: non-bituminous, with less than 11 per cent. of volatile matter; semi-bituminous, containing from 11 to 16 per cent.; and bituminous, containing from 16 to 21 per cent.

The 83 separate coal concessions in the Province of Liége extend together over 38,666 hectares (95,549 acres); and in 1903 the 73 separate plants put out 6,478,110 tons, the largest output yet attained. The number of hands employed is about 35,500; and seven women are still working underground, though no others are taken on, in accordance with the new regulations. The collective force of the engines is 46,550 h.p. nom., including 1,630 h.p. for generating electric current, not merely for lighting and surface plant, but also for driving fans and pumps. The generating station at the Espérance et Bonne Fortune Colliery comprises three 1,000-volt triphase dynamos; and an electric winding engine with Ilgner group for starting and regulating is in successful operation.

The largest colliery in the province is that of Marihaye, distinguished by its complete suppression of explosives, and their replacement by mechanical means, especially the Dubois-François "bosseyeuse," or heading-driver, which first drills a hole in the rock, and then drives a multiple wedge of circular section for bringing down a mass. A considerable portion of the output, 550,000 tons, is coked in Colin and Semet-Solvay by-product recovery ovens, the coke being highly esteemed for use in the blast furnace and cupola.

Most of the Liége collieries are united in a syndicate, whose collective exhibition at Paris in 1900 was awarded a "grand prix"; and most of them also belong to the Union des Charbonnages, Mines et Usines Métallurgiques, which was founded in 1866 for protecting trade interests, and has been the means of bringing about many important reforms, social, economical, and technical.

The Province of Liége contributes a preponderating share in the kingdom's metallurgical production, the total value of the

mineral and metallurgical products being returned as 321,268,225 francs (£12,850,729). In 1903 the blast furnaces turned out 606,091 tons of pig iron, and the rolling mills 76,103 tons of finished iron, with 536.356 tons of finished steel. Lead pigs were produced to the tune of 16,749 tons, with more than 30 tons of silver, while 118,420 tons of zinc were cast and 42,281 tons rolled.

Liége is practically the cradle of the zinc industry, because the company which is earliest in date, as it is first in importance, owes its origin to the Altenberg, or Vieille Montagne, in the neutral territory of Moresnet, adjoining what is now the Province of Liége, and the calamine deposit of which is mentioned in a concession dated 5th July, 1435. After the Belgian provinces were annexed to France in 1795, the mines were worked by the Government of the republic, but without satisfactory results. In 1806 Napoleon granted them in concession to Daniel Dony, a Liége chemist, with the obligation of conducting experiments in view of reducing the ore to a metallic state. Dony endeavoured to melt the calamine in a reverberatory furnace at Liége, and, supposing that it was not raised to a sufficiently high temperature, mixed it with coal-dust. In order to see what passed in the furnace, he fitted a flower-pot to the furnace front, and was astonished to soon observe, through the small hole in the bottom, the zinc vapours condensing in drops on the inside of the projecting flower-pot, colder than the furnace.

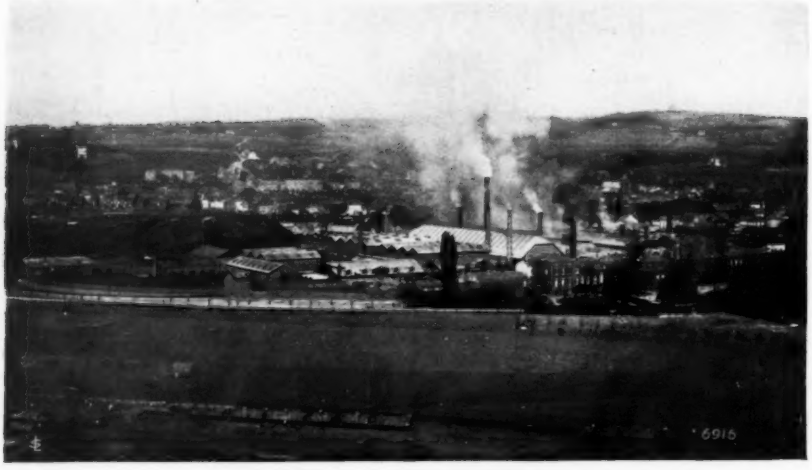
Thus was discovered, more by luck than judgment, the Liége method of reducing zinc ore, the principle of which remains unchanged, though the plant has been gradually improved and the yield increased. The heirs of David Mosselman, who succeeded Dony in 1818, ounded the Vieille Montagne Company, with a capital of 7,000,000 francs (£280,000), their patrimony comprising the "Old Mountain" at Moresnet, the Liége foundry, works that were being put up in the neighbourhood at Angleur, and two rolling-mills in France. From this small beginning the company has gone on increasing its possessions in various parts of the world, including England, and extending its importance, while always paying a dividend of 25 per cent., notwithstanding fluctuations in the price of zinc; but the headquarters are still at Angleur-lez-Liége.

At Moresnet, mechanical rock-drilling with compressed air was employed nearly fifty years ago; Wolf put down his first double-cylinder pumping engine, and Clay introduced his first rotary pumps. There and at Angleur crucibles were first made by machinery, the quality being improved as well as the output increased; and the company was the first to use zinc sheets for roofing, with great increase of strength, lightness, durability, and cheapness, while the old metal is always worth half its first cost.

An Englishman who came as a godsend to Liége is the famous John Cockerill, who in 1817 received from the King of Holland (with which Belgium was then incorporated) the château of Seraing and its dependencies, formerly the palace of the Liége bishop-princes, with the mission to put up engine works. Fortunately for the development of these works, the Meuse valley, generally narrow, here widens out considerably, and has permitted that remarkable extension which eventually rendered these works in some respects the largest and most complete in the whole world, combining as they do coal-mining, iron-smelting, steel-making, and machine construction under one management.

In 1824 a coke-fired blast furnace was blown in, which, though not the first on the Continent, as has been stated, was the first provided with a steam blowing engine, so that its working was excellent and its production high, thus revolutionising the pig iron manufacture. Between 1825 and 1827 Ericson designed and began a steam vessel that was to receive high-pressure boilers with internal flues and forced draught, and also compound engines with surface

PERRON PLANT OF THE BOIS D'AVREY COLLIERY.



THE VIEILLE MONTAGNE CO.'S WORKS AT ANGLEUR.

condensation; but, these improvements in advance of the age, were not carried out. In 1835 the first rail on the Continent was rolled, and the first locomotive made; and in 1851 Von Engerth got out his powerful engine for drawing heavy loads and mounting steep gradients. At Seraing a great deal of the plant used in driving the Mont Cenis Tunnel was constructed; and the Cockerill works were the first on the Continent to make steel by the Bessemer process, the converters being started in 1863.

Two of the company's engineers, in conjunction with the late Delamare-Debouteville, induced the general manager to make large gas engines for the direct utilisation of blast-furnace gas; and it is estimated that, used in this way, the gas exerts five times the power it affords when simply used for firing boilers, while this utilisation has the collateral advantage of reducing the cost price of the pig-iron turned out.

At the death of Cockerill, in 1840, his nephew, Gustave Pastor, formed a public company; and among successive improvements have been the founding of branch works at St. Petersburg and the laying out of a shipyard at Hoboken, near Antwerp, whence the turbine 3-screw steamer, "Princesse Henriette-Elisabeth," of 23 knots calculated speed, was successfully launched on 30th March for the mail service between Dover and Ostend. Not finding its three collieries at Seraing sufficient to afford the fuel supply required, the company bought a portion of the adjoining Espérance concession and participated in the iron mines of the Société Franco-Belge at Somorostro, while also acquiring other mines in Luxemburg and Meurthe-et-Moselle. New steel works were put up in 1872, and a wheel shop in 1885, so that, with other additions, the Seraing works now extend over 108 hectares (267 acres), of which 15 hectares (37 acres) are built over.

The capital of the Société John Cockerill is now 10,000,000 francs (£400,000), fully paid up; and the following figures will give an idea of the importance of this Belgian company founded by an Englishman. The yearly output of coal is 260,000 tons; of coke, 124,000 tons; of iron ore, 300,000 tons; of pig iron, 220,000 tons; and of rails, tires, rolled steel and cannon, 130,000 tons, with 7,000 tons of castings and 1,500 tons of various mechanical parts, while the number of workmen varies from nine to ten thousand.

The original Ougrée Smelting Company, founded in 1835, subsequently absorbed the finished iron works of the same name, and in 1900 united with the Marihaye colliery, above referred to, assuming the style of "Société Anonyme d' Ougrée-Marihaye," with a capital that is now 21,297,000 francs (£851,880). The iron smelting division, which employs 1,250 hands, turns out 136,000 tons of basic pig by four blast furnaces, of which No. 4 is of large capacity, provided with four Cowper stoves

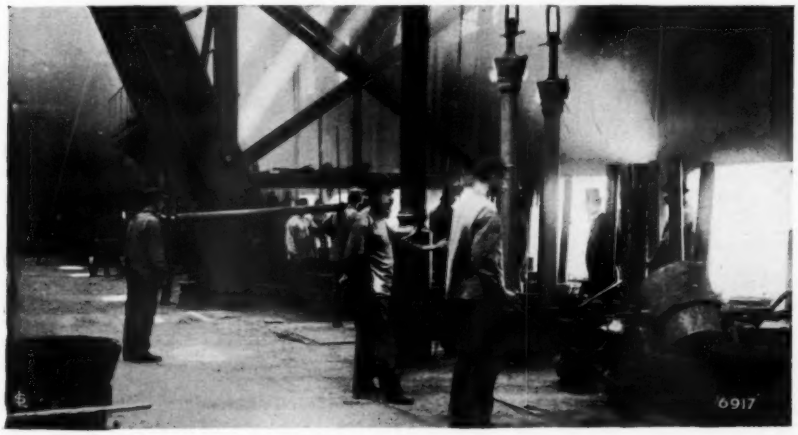
and fitted with an inclined lift for automatically tipping the charge into the mouth. A fifth furnace, ready for blowing in, is constructed in line with Nos. 1, 2, and 3, for their being charged successively by an electric overhead travelling crane. The blast is supplied by Cockerill blowing engines, two working with steam and two with blast-furnace gas.

The steel-works division, which covers 37 hectares (91 acres) and employs 2,140 workmen, produced last working year 266,000 tons of Bessemer, basic, and Siemens-Martin steel, all of which was worked up in the form of joists, rails, sleepers, angle-bars, axles, tires, plates, etc. The company owns patented processes for making rack-rails for mountain railways, and for casting hollow ingots to be drawn into tubes. The plant comprises a 100-ton mixer, three cupolas, four 12-ton basic converters, two 15-ton Siemens-Martin furnaces, a 1,500-h.p. blowing engine (with another in reserve), and roll-trains of various sizes, some of which are driven electrically. Of the electric current generated at the central station in the blast furnace division, 2,200 h.p. are utilised for power, and 300 h.p. for lighting. Besides its own colliery on the spot and its union with Marihaye, the Ougrée Company owns five-eighths of the Six-Bonniers Colliery, and is in treaty for buying up the remaining three-eighths.

Great excitement was lately caused at the "Bourse des Métaux" by the news that Ougrée-Marihaye, already sufficing unto itself for the supply of raw materials, had amalgamated with the smelting companies of Vireux and La Chiers in France and Rodange in Grand-ducal Luxemburg, thus attaining, remarks a Brussels contemporary, a unique position in the world's industry.

The Société Anonyme des Aciéries d'Angleur, which was formed in 1878, with a capital now raised to ten million francs (£400,000), employs 2,500 workmen. Though raising the great bulk of the iron ore supply from its own mines in Grand-ducal Luxemburg and Lorraine, it has not yet, like other large iron and steel companies, entered into partnership with a colliery, but purchases its coal and coke, of which latter about 330 tons daily are made at the works, and 170 tons imported from Germany. The direct utilisation of blast-furnace gas is, however, under consideration, and it is decided to lay down new plant, so as to double the output of basic steel ingots, which is now 150,000 tons per annum; but the making of finished iron is quite given up, and the site of the puddling furnaces knows them no more. The company has two distinct divisions, of which the Renory works, near Ougrée, on the right bank of the Meuse, contain four Bessemer converters and a Martin open-hearth furnace, kept in reserve in case of over-pressure or break-down in the other division. Two small Walrand converters are capable of producing from two to three thousand tons of steel castings yearly; and steel forgings, tires, and axles form a special feature.

The principal works are, however, at Tilleur (on the left bank of the Meuse,



PIPE FOUNDRY, CIE GÉNÉRALE DES CONDUITES D'EAUX.

OUGRÉE IRON AND STEEL WORKS.

opposite Seraing), where five lines of way bring up the ore, and two the coal and coke, having on either side of each a small-gauge tramway, for rapid discharging, that leads directly to the charge lifts of the four blast furnaces. The latter, each of which has four Cowper stoves, turn out daily about 400 tons of basic pig; but by enriching the charge with 20 per cent. of Gellivara ore the output is increased to 500 tons and upwards. The metal, run directly into a ladle, is conveyed to the steel department, where the three 12-ton converters are separated from the casting pit, so that the men are not subjected to splashes of molten metal. The ingots, treated in Gjers soaking pits or reheated, are taken to the roll-trains, the largest of which turns out joists up to 40 centimetres (16 inches) high. Small and medium ingots are cast in a separate pit of rectangular form, served by electric overhead travellers, taking their current from an independent generating station. Rails up to 27 metres (88½ feet) long are drilled and pared to dead length by machines driven electrically. Electromotors also drive the slag-grinding mills for making cement on the spot; and the company has lately acquired some adjoining works for grinding basic slag to be used as a fertiliser.

The moulders of the Liége district are noted for their skill in forming moulds from the drawing only, without pattern. The art of moulding was practised and iron castings were produced so early as the thirteenth century. Among the earliest foundries is that of the Vennes, owned since 1865 by the Compagnie Générale des Conduites d' Eaux, which was founded in that year with a capital of 10,000,000 francs (£400,000). By 1880, after only fifteen years' working, all the paid-up capital had been returned to the shareholders; and the new capital, constituted by the remainder of the assets, was divided into 5,000 shares without indication of nominal value, which have since been increased to 15,000, for extending the company's means of action and enabling it to engage, by contract or otherwise, in waterworks enterprise, however considerable, in Belgium and other countries.

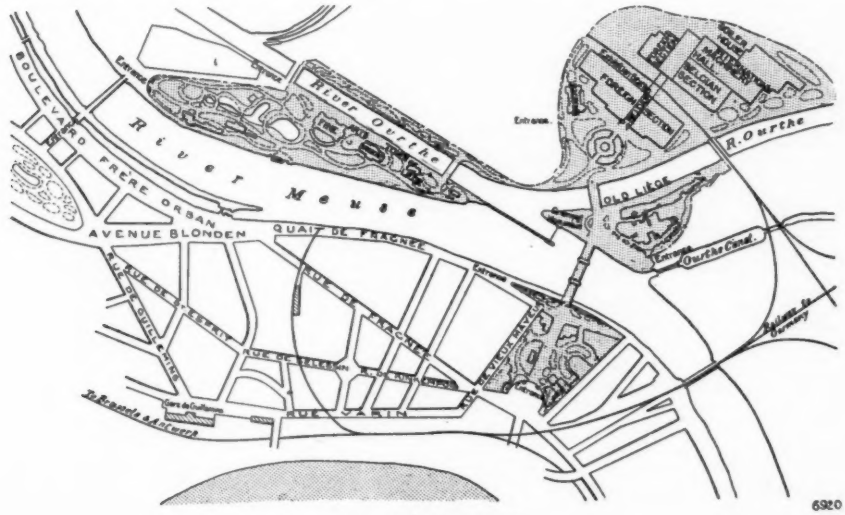
The Vennes works, connected with the Meuse and also with the railway between Brussels and Cologne, comprise two foundries for casting vertically all descriptions of pipes, and another for mechanical parts, with pattern shops and machining department. All the pipes, whether flange or spigot and socket, are cast, in dried loam moulds, of a metal formed by mixing the best English, Scotch, French, Luxemburg, and Belgian pig-irons, melted in the cupola. In addition to perfect homogeneity and

great density, the thickness of metal is absolutely uniform over the whole length and also over the whole circumference of the pipe. The largest pipes usually turned out are 4 metres (13 feet) long and 1·25 metre (4 feet) in diameter; but both dimensions can be increased if required. A hydraulic machine permits of testing up to 150 atmospheres and even more. The great strength of the pipe is obtained without any rings or feathers cast on. Bends, even those of largest radius, are cast without any support, so that they are as strong and regular as straight pipes.

The works now cover an area of 150,000 square metres (179,405 square yards); and the number of workmen is 750, without reckoning those engaged at waterworks in various parts of the world put up by the company, and in many of which, as at Rome, Bucharest, Barcelona, and Santander, it is pecuniarily interested. The mean annual production exceeds 30,000 tons, of which 70 to 80 per cent. are exported; and more than 110 tons of castings have often been turned out in a day of ten hours.

In 1825, Regnier-Poncelet started works near the Porte Saint-Léonard of the city, and in 1836 formed the Société Saint-Leonard, first for making iron and steel, and subsequently for machine construction. Its first steam engine, finished in that year, drove a Liége flour mill for half a century; and in 1842 a steamboat, the "Espoir," was constructed for passenger service on the Meuse, between Liége and Namur. Although all the available land adjoining the works was gradually annexed to them, they proved insufficient for the growing business; and the foundry was transferred to Herstal, three miles off. The machine-tools and overhead travellers at the original works are now driven electrically; and 600 workmen are employed. The speciality and great bulk of the work has long been locomotives, both narrow and standard gauges, of which the company has established well-marked types; and lately some compressed air "locomoteurs," or self-moving carriages mounted on two bogies, each provided with a pair of outside cylinders, have been supplied for the Paris underground suburban traffic of the Ouest Company. A recently added branch of manufacture is that of Körting gas engines, four-period single acting up to 200 h.p. and two-period double acting for higher powers working with coke-oven, blast-furnace, or other poor gas.

Les Ateliers de la Meuse, at Sclessin, on the left bank, employing about 500 hands, turn out all descriptions of engines, but chiefly winding engines with lifting-valves and underground pumping-engines. A 110 h.p. steam engine, designed to work with superheated steam, is completed for driving a 240-volt × 1,875-ampere dynamo, to supply the shops with motive power; and the trial showed it to work with



PLAN OF LIÉGE EXHIBITION.

a steam consumption of less than 5 kg. (11 lb.) per h.-p. per hour. This engine will first figure at the Liége Exhibition, as also a winding engine fitted with automatic expansion gear for raising 350 tons daily from a depth of 1,200 metres (610 fathoms); and a very large locomotive, with four cylinders but not compound, for working with superheated steam, made for the Belgian State railways, will also be exhibited.

Near these works are those of the Escaut et Meuse, that produce wrought-iron pipes from rolled plates drawn through a die, where the lap joint is welded up.

At Jemeppe-sur-Meuse, opposite Seraing, the engine works of the Société Maison Beer comprise a mechanical laboratory in connection with the Liége University, with experimental boiler and engine, that permitted Professor Dwelshauvers-Dery to conduct his searching investigations into the thermic effect of the steam engine.

Owing to the difficult navigation, steamers have long since ceased to ply on the Meuse above Seraing; but there is a half-hourly service of "bâteaux mouche," between that place and Liége, and also a well-appointed steam tramway (now being transformed for electric working) that serves the busy sub-centres on the left bank. The visitor, taking the boat at Seraing or the tramway at Jemeppe opposite, leaves behind him the Cristalleries du Val Saint-Lambert and the Marihaye Colliery, and passes successively the various works above mentioned, as well as many others, that extend almost uninterruptedly along either bank of the river.

Liége owes, and has owed from a very early period, a considerable portion of its prosperity to the manufacture of arms, for which it is well known to be the most important centre in the whole world. Between 1820 and 1860 the mean annual production of firearms was 423,707; and in 1900 the number made attained 2,319,689.

At the present time about 41,500 persons (men, women, and children) in Liége and its neighbourhood are engaged in this industry, which is essentially a home one. For a long time it remained in the hands of small manufacturers, who gave out the work in its successive stages to those employed; and the latter either furnished the separate parts or one after another took the growing piece, so that it passed through a great many hands and was brought many times to head-quarters before final completion. It is quite common even now, in the streets of Liége, to see a woman carrying a few rifles in various stages of manufacture.

In 1885 a group of gunmakers formed themselves into a company for being able to quickly execute large orders; and in 1889 the Société des Fabricants d'Armes de Guerre Réunis founded the National Arms Manufactory at Herstal, completed in 1891, occupying 9 hectares (22 acres). It comprises three distinct departments, viz., one for making small arms, another for cartridges, and the third for bicycles and motor-cycles. The works, completely surrounded by a line of way, are remarkably well laid out, no material or part ever passing twice over the same ground.

The firearms department is provided with the most improved automatic machines for producing the various parts; and fowling pieces are now made as well as rifles, of which more than 800 can be turned out daily. At the present time, however, the great bulk of the work consists of bicycles, of which the daily make is 150, and of motor-cycles 50, while the works have actually turned out as many as 10,000 cycles in a single year. All the parts of the Bowden bicycle brake are made at Herstal, as for a long time were all the cartridges for "sparklets."

The Liége Arms Museum, subsidised by various administrations and also by the Armourers' Corporation, was opened in 1885, and now contains more than 4,000 specimens, beginning with the cross-bow. It is remarkably rich and complete, possessing a library, publishing a technical magazine, and giving a course of practical lectures on the manufacture of arms.

While English technical instruction was formerly reproached with too much sacrificing theory to practice, and that of Germany with just the other extreme, the Liége University, founded in 1817, and now attended by 1,600 students under 60 professors, has always been credited with hitting the happy mean, and affording its engineering students sound and systematic teaching, backed up by ample opportunity for practice. The technical faculty comprises four sections: mining, arts and manufactures, mechanical engineering, and electrical engineering. The last-named course is given at the Electro-Technical Institute, added by Senator Montefiore-Levy in 1885, and now placed under the direction of Professor E. Gérard, the well-known electrician, assisted by Professor de Bast.

The Liége Engineers' Association, restricted to former students at the technical faculty of the University, is the most important engineering society in the country, and now comprises more than 1,400 members, distributed over various parts of not only Belgium, but the whole world. Its

fiftieth year of existence was worthily celebrated in 1898; and last autumn several members visited Great Britain (not for the first time, however) at the invitation of the Iron and Steel Institute. It is the Liége Engineers' Association which, in accordance with a resolution of the Paris Mining Congress in 1900, and at the request of the Union des Charbonnages, is organising the International Congress of Mining, Metallurgy, Mechanics, and Applied Geology, to be held at Liége from 26th June to 1st July next in connection with the Exhibition.

Brussels, the metropolis, and Antwerp, the commercial capital, have each held two general official exhibitions, which were all international except that of Brussels in 1880; but, as a set-off, the Brussels Hygiene and Life-saving Exhibition in 1876 was international, the British commissioner being the late Polydore De Keyser, afterwards Lord Mayor of London. Liége, however, the manufacturing capital—the Birmingham of Belgium, as it has been called—has hitherto been left out in the cold, for the Contractors' Congress and Exhibition, held within its walls in 1881, if international, was limited to its special object.

Like Düsseldorf in 1901, however, Liége was anxious to show her progress and manufacturing capabilities, as well as to take at least an equal share with Brussels, Antwerp, and Ghent in a fine art display. Besides, several public works and improvements were required for the city; and it was thought that a great exhibition might well aid in defraying their expense. The year 1903 was first proposed; but the present was eventually fixed upon, as coinciding with the seventy-fifth anniversary of Belgium's independence and separate existence. The movement was taken up warmly, with the active support and pecuniary subvention of the State, the Province of Liége, and the Municipality, due in a great measure to the King's influence. Thanks to the rapid sale of several series of lottery tickets, the financial success of the undertaking is already secured; and its technical success is placed beyond a doubt through the space taken up by Belgium itself and other nations, and also by the entries of important exhibits. In order to increase the usefulness of the Exhibition and save visitors trouble in seeking for the objects that interest them, the Executive Committee has decided to add an inquiry and information office, technical and commercial, with reading room, telephone cabins, etc., and also a staff of officials, instructed to give full but impartial information as to any class of exhibits by various countries, with freights, carriage rates, customs' dues, etc.

The Exhibition grounds extend over an area of 660,000 square metres (789,382 square yards), larger than that of the last great Exhibition (Düsseldorf); and more than 100,000 square metres (119,603 square yards) are under roof. The Machinery Hall, Railway Department, Boiler and Gas-producer House, cover together 30,000 square metres (35,881 square yards), of which the Société Cockerill alone occupies 1,200 square metres (1,435 square yards), and the Ateliers de la Meuse 615 square metres (735 square yards). The space reserved for Belgium itself is 45,000 square metres (53,821 square yards); and France has secured 20,000 square metres (23,920 square yards), Germany half that space, Great Britain, for which Mr. J. Kiralfy, 35, Great Tower Street, London, is the commissioner, 1,900 square metres (2,272 square yards), Italy 2,000 square metres (2,392 square yards), Switzerland 1,000 square metres (1,196 square yards), Russia 1,500 square metres (1,794 square yards), and Japan 1,400 square metres (1,674 square yards). Spain, Greece, Holland, Luxemburg, Turkey, Persia, China, and the United States participate in the general show; but Canada, Sweden, Servia, Bulgaria and Montenegro have put up separate pavilions.

The Meuse flows generally from south to north through the middle of the city; and the Ourthe makes with it, at the confluence, a sharp point of land. It is here that a colossal monument to Gramme, inventor of the dynamo, who was born at Huy, in the province of Liége, is being erected; and to the south is an artistic reproduction of Old Liége, comprised in the Exhibition. This portion is connected, by the new Pont de Fragnée over the Meuse, with the restaurant and recreation department, and also, by a new bridge over the Ourthe, with the Belgian and Foreign Industry Courts and Machine Halls. Right in the middle of this, the Vennes group, is the large Exhibition station, traversed by a branch line in connection with the Belgian State and Nord Belge railway systems.

Opposite the Gramme monument is the Boverie group, containing the Government, Municipality, Fine Art, and Ancient Art palaces. The Exhibition is to be opened on April 27th by Prince Albert of Belgium, heir apparent to the crown.

House Drainage.—II.

By GERARD J. G. JENSEN.

HAVING thus disposed of the horizontal or underground portion of the drainage system, it will be necessary to consider the ventilation of the vertical piping—that is, of soil, waste, and rain-water pipes. Soil-pipes—by which are generally understood the discharge pipes of water-closets, but which also include the outfall pipes from housemaids' slop sinks and urinals—being provided for the removal of excrementitious matter, must be connected to the underground drains direct. Their air inlets are therefore provided by the drains upon which they are fixed, and which, in most cases, they serve to ventilate. The pipes must consequently be carried up without restriction in area to some point above the ridge of the roof, as already recommended, their ventilation being thus provided for in arranging that of the underground drains.

Waste pipes, which comprise the discharge pipes of lavatories, baths, and sinks, derive their fresh air at their outlets, which, as already stated, must discharge openly over surface traps. Their ventilation outlets, if the pipes be long, should be arranged at some point slightly higher than the eaves of the roof (see Fig. 12), as it is obvious that long pipes provide a considerable area of fouled surfaces, the effluvia from which is neither pleasant nor wholesome. The very prevalent practice of ventilating large waste pipes by the insertion of hopper-heads (as in Fig. 13)—which, by the way, are usually in dangerous proximity to windows—cannot be too strongly condemned for this reason. Short waste pipes, from fittings on the ground floor, are, on the other hand, sufficiently and inoffensively ventilated through "puff" pipes carried through the wall into the open air, as shown in Fig. 14.

The question of ventilation for rain-water pipes is disposed of by pointing out that both their inlets and outlets are open. The pipes being inoffensive if, as they should be, kept distinct from waste pipes, no inconvenience can result from them, whatever their position.

The only point which remains to be discussed under the heading of "Ventilation" is the question of trap ventilation. Not infrequently two or more closets, or other appliances, situated at some little distance from each other (each of which must be trapped separately at its outlet), are made to discharge into the same vertical outfall pipe. Under such circumstances, the traps of the lower appliances are liable to lose their seals through one or other of two causes, namely, (*a*) through the suction produced by the falling of a column of water from the apparatus above, and (*b*) by the contents of the traps being forced out through the compression of air in front of the falling water. Both these contingencies must be most carefully guarded against, and the means for doing so efficiently is to be found in allowing a free vent for the air in every case, whether it be one of pressure or of suction. This vent is provided by a so-called "anti-syphonage pipe," branched out from the lowest trap and continued up to receive on its way branches from the remaining traps. The anti-syphonage pipe may then be continued up to the same level as the ventilation pipe of the soil or waste pipe into which the traps discharge, or it may be branched into it at some little distance above the level of the uppermost fitting, as shown in Fig. 15. Similar remarks to the above apply equally to a horizontal tier of traps, of which an example is shown in Fig. 16. An arrangement of the kind shown in this illustration, in addition to preventing trap syphonage,

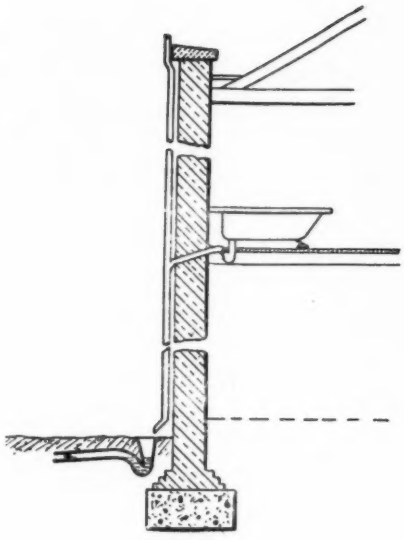


Fig 12

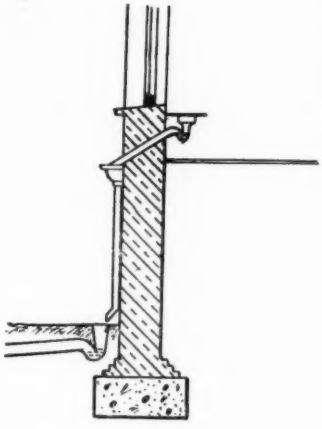


Fig 13

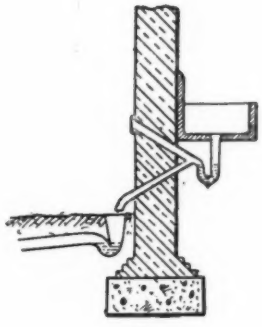


Fig 14

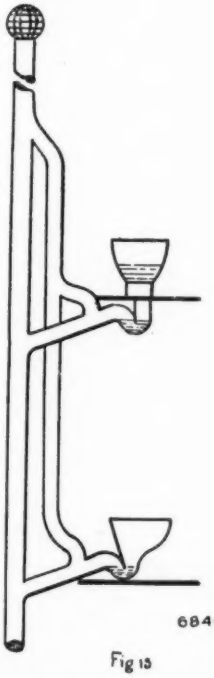


Fig 15

will also rectify another frequently neglected matter—the ventilation of the "dead ends" of waste pipes.

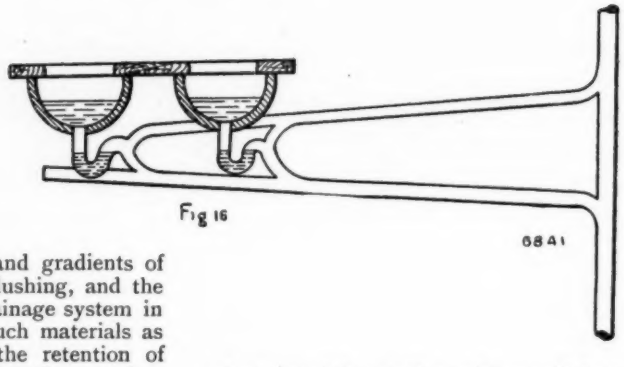


Fig 16

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The fourth of the objects which must be aimed at in designing a drainage system is dependent upon the dimensions and gradients of the drains, thorough flushing, and the construction of the drainage system in such manner and of such materials as to render impossible the retention of foul matter, be that by deposit, retention, or absorption.

Dimensions.

A needlessly large drain is entirely adverse to the principles of sanitation and economy, for the efficiency of the drain is not increased by the fact of its being larger than actually necessary; it is, on the contrary, greatly impaired. Whilst, in the case of a 4-in. drain, the available flow of sewage may be sufficient to make to run full and thereby enable the drain to be self-cleansing, the same quantity of sewage will cause a 6-in. drain to run less than half-full, and a 9-in. drain only about quarter-full. It is, therefore, obvious that where such large pipes are used, when a smaller drain would be capable of removing the sewage, there must be a considerable extent of unflushed surfaces upon which sediment is deposited and allowed to remain until destroyed by decomposition. Moreover, given two drains of unequal diameter, laid at the same inclination and conveying the same quantity of sewage, the velocity, and, therefore, the flushing power, of the flow in the smaller pipe will be greater than that of the flow in the larger, because the depth of sewage in the former is greater than that in the large pipe. It will thus be seen that an unnecessarily large drain will always remain in a more or less foul condition; whilst a small drain will always be comparatively clean. In addition to this, the first cost of the smaller and more efficient drain will be much less than that of the larger.

The maximum hourly flow of sewage and storm water to be disposed of by each drain being ascertainable, and the discharging capacities of drains laid at various gradients being known, it is not a difficult matter to calculate the diameters of drains for any specific case. There is, therefore, no excuse for guesswork, or for the provision of an unnecessarily large drain so as "to be on the right side." At the same time, great as are the virtues of a small drain, the piping made use of must not be too small. A good rule is to provide a drain which will remove the probable maximum hourly volume of sewage, etc., with a depth of flow equal to seven-eighths of the diameter of the pipe. This is the mean proportion between five-sixths and eleven-twelfths of the diameter, at which depths are respectively obtained the maximum mean velocity of flow and the maximum discharge. The adoption of this rule will cause the provisions of drains which will permit of a slight increase in the volume of the sewage without flowing full, and of a slight decrease without loss of scouring force.

No drain should, however, be less than 4 in. in diameter. This should also be the maximum size of branch drains, and will be found ample for all requirements of such, even in large institutions. Main drains may have to be larger, but unless there is a *constant* large flow of

sewage, it will in such cases be desirable to sub-divide the drainage system into sections, utilizing two or more drains of small diameter in preference to one of large calibre. Similarly, it may also be possible to provide a small, say a 4-in., drain for the sewage proper and a small portion of rainwater, and an entirely separate drain of suitable dimensions for the remainder of the rain and surface water.

Gradients.

The gradients to which drains are laid must, to a very great extent, be governed by the nature and the natural contours of the ground, no less than by the difference in level between the lowest point to be drained and the sewer or other outfall.

So far as these considerations will permit, all drains must be laid to self-cleansing gradients—that is, they should be laid with such falls that the mean velocity and the depth of the normal flow through them will be such as to float all solids through the drains and into the outfall. The normal flow of sewage is, in calculations, taken to be equivalent to a stream having a depth equal to one-quarter of the diameter of the drain; and as it is found that this stream is capable of keeping the drain free of deposit, if travelling at a rate of 3 ft. per second, it follows that the gradients of drains must be such as will ensure this velocity, viz.:—

For a 4-in.	drain,	or fall of	1 in	42
,, 5-in.	,,	,,	1 ,,	52
,, 6-in.	,,	,,	1 ,,	62
,, 9-in.	,,	,,	1 ,,	95
,, 12-in.	,,	,,	1 ,,	127

These gradients should be adhered to as far as possible. In the event of it being impracticable to lay the whole of the drains to the above falls, the main drain may be laid at a flatter gradient and provided with means by which it is flushed automatically. In this manner it is frequently possible to avoid sacrificing the self-cleanliness of branch drains. If, on the other hand, local circumstances would permit much steeper gradients, it will still be advisable to adhere to the falls named, as the flow through steep drains is frequently at such a high rate of velocity as to render the hydraulic depth insufficient to float fæcal matter to the outfall.

British Standard Steel for Marine Boilers.

Report No. 14 of the Engineering Standards Committee contains a specification for structural steel for marine boilers. The stipulation as to the process of manufacture is that the steel shall be made by the acid or the basic open hearth method, as may be specified and as approved by the inspecting body. Tensile tests are to be performed upon specimens in accordance with the standard fixed by Report No. 18, a copy of which is printed as the appendix to the present specification. The following is a summary of the tensile tests referred to:—

Form.	Purpose	Tensile strength tons per sq. in.	Elongation (minimum) in 8in. length. Percentage.*	Number of Tests.
Plates	Shells and girders	28-32	20	1 each plate rolled.
,, ...	Flanging and welding	26-30	23	1 ,, ,,
Bars	Stays, &c.	28-32	20	2 each charge of 15 bars.
,, ...	,, in combustion chambers ...	26-30	23	2 ,, ,, ,,
... ...	Rivets	26-30	25	2 ,, ,, ,,

* For thicknesses of ·375 and upwards. For thicknesses under ·375 in., elongation may be not more than 3 p.c. below the percentages stated in the table.

For cold bend and temper tests the specimens are not to be less than 1½ in. wide, and in temper tests the samples are to be heated to a blood red and quenched at a temperature not exceeding 80 deg. Fahr. In both cold and temper bends the test pieces shall be capable, without fracture, of being doubled over until the sides are parallel, and the internal radius is equal to one and a half times the thickness of the specimen. The number of bend tests is fixed at one from each plate as rolled, and one from each angle or stay bar rolled. Bend tests are not required in the case of rivet bars, as the specification provides for the testing of finished rivets in the following manner:—(*a*) The rivet shanks are to be bent cold and hammered until the two parts of the shank touch, without fracture; (*a*) the rivet heads are to be flattened while hot until the diameter is two and a half times that of the shank, without cracking at the edges.

The Stability of the Aswan Dam.

DURING the last few weeks various alarming statements have been made in the daily press with regard to the stability of the masonry dam across the Nile at Aswan, which has been fully described in previous volumes of this review.* The origin of the mistaken reports recently published is very easy to trace.

In autumn last year, Sir William Garstin decided to recommend, among other works for increasing and improving the water supplies of Egypt, that the Aswan dam should be raised by about six metres. The effect of this additional height would be to increase the volume of water stored in the reservoir from 35,000,000,000 cubic feet to about 70,000,000,000 cubic feet. After consultation with Sir William Willcocks, late Director-General of Reservoirs, and after making all the necessary calculations, Sir William Garstin felt satisfied that the reduced factor of safety would still be amply sufficient, even for a work of such national importance. Accordingly, he sent in a report to the Public Works Ministry advising the execution of the additional works.

Before anything was done, the opinion of Sir Benjamin Baker was invited, not exclusively, as some have ignorantly imagined, upon the question of raising the dam but also upon other important matters of detail. In the course of correspondence, Sir Benjamin Baker most properly mentioned the fact that certain mathematicians had recently propounded a novel theory directed to the elucidation of some disregarded points in the stability of masonry dams in general. No conscientious engineer can dismiss without attention any theory that may appear likely to throw new light upon the strength or stability of the works in which he is professionally interested. Hence, it was only natural that Sir Benjamin should desire to inquire into the merits of the theory in question. But this was not by any means the chief reason for his recent visit to Egypt, which was undertaken at the request of the Egyptian government for the purpose of personal study as to the effect of two years' regulation of the dam. Foremost among matters requiring consideration was the condition of the river bed on the down-stream side of the work. We may here explain that it was found long ago that erosion was being caused by the discharge of water from the reservoir. With the object of ascertaining how far this might be prevented, masonry aprons were built experimentally along short sections of the dam, and the main purpose of the visit made by Sir Benjamin Baker was to examine the condition of these protective works.

After the inspection had been made, it was considered advisable to continue the apron along the whole length of the dam, a work that could scarcely be completed in less than two years. As the holes scoured away in the river bed are fully 40 feet away from the toe of the dam they do not constitute any source of danger, but it is very necessary that they should be prevented from approaching nearer. Naturally, no one would think of raising the dam until after the completion of the new apron, and after hearing the opinion of Sir Benjamin Baker the Egyptian authorities decided to postpone for the present any addition to the superstructure of the Aswan dam.

This conclusion was the result of a report made by Sir William Garstin, a document in which the necessity for protecting the river bed was urged, and mention was also made of the new theory.

* Vol. VIII., pp. 300 and 518.

The alarmist statements recently published appear to have arisen from the excessive avidity of some news purveyors for sensational reports, and there is absolutely no justification for them in the report of Sir William Garstin. To engineers, who know the principles underlying masonry dam design and the large factor of safety almost invariably allowed, the idea that a new theory could affect the safety of the Aswan dam must appear ludicrous in the extreme. A theory may be right or it may be wrong, but it cannot in any way alter facts. In the present case, the fact is that the Aswan dam has a factor of safety of about 100 per cent. more than the factor allowed for many notable works, the stability of which has been conclusively proved by practical experience. Even if raised by adding some six metres of masonry the dam would still have a factor of safety comparing favourably with other engineering works of similar character.

Still, before finally commencing the operation, it is well that full inquiry should be made into the latest theory, and that careful consideration should be given to the point as to how far it may be justifiable to reduce the very large factor of safety now existing in a work upon which Egypt depends to so great an extent.

The new theory mentioned above is contained in a paper which forms one of the Drapers' Company Research Memoirs and was written by Mr. L. W. Atcherley, a demonstrator of applied mechanics at University College, London, assistance on points having been given by Professor Karl Pearson, also of University College. We may at once say that the paper in question was written without reference to any particular dam, and is merely a suggestion as to the probable behaviour of masonry dams in general when holding up water to the full intended level.

Although presented with an accompaniment of somewhat complicated mathematical equations, the point raised by Mr. Atcherley is really quite simple. His view is that engineers are not correct in considering the only possible line of fracture in a masonry dam to be horizontal. He contends that even if the proportions of a dam be such as to prohibit fracture in a horizontal plane, there may still be a liability to fail along a vertical plane, through the toe, owing to the development of tension along the base of the structure. With the object of making clear the line of reasoning followed, let us first take the case of a dam designed in accordance with the principles hitherto accepted. We assume the structure to be a right-angled triangle, the vertical side being the face exposed to water-pressure, the horizontal side being the base and the sloping side the back. Considering any horizontal section it is clear that all water pressures above the section tend to cause rotation about the centre of the same section. This effect has to be balanced by some other force, which is provided by the weight of the triangular mass of masonry above the assumed horizontal section. The force thereby originated, acting downwards through the centre of gravity of the triangle, also tends to cause rotation about the centre of the assumed horizontal section but in a direction opposed to that due to water pressures. If the two forces be in equilibrium, the structure will possess no factor of safety and must be in a critical condition, for the slightest increase of the water pressure will result in tensile stress between the centre of the horizontal section and the end at the face of the dam. Consequently, as the tensile resistance of masonry is very small, fracture would take place along a horizontal plane The corresponding risk of failure by crushing of the masonry between the centre and the outer end of the horizontal section would be far less owing to the much greater resistance of masonry to compression. By suitable adjustment of the proportions, the value and direction of the force due to the weight of masonry can be controlled so that the force shall always be far greater than that representing water pressure, thus guarding against the possibility of tensile

stress at any point on the assumed horizontal section, and giving an adequate factor of safety. By designing the structure so that the lines of resultant pressure, for reservoir full and reservoir empty, fall entirely within the middle third of the structure, a guarantee is afforded that no tensile stress can be developed either on the face or back of the dam.

These principles and conditions have been regarded as of paramount importance by engineers for many years past, and they have been realised with every satisfaction in numerous masonry dams in all parts of the world.

Mr. Atcherley now comes forward with a purely theoretical assumption that tension along the base of a dam may be a greater source of danger than tension along the face. His idea is that engineers and mathematicians have overlooked the possibility which he suggests as a certainty. The new theory includes the hypothesis that the upward pressure distributed over the base of a dam, and tending to cause rotation about the centre of any assumed vertical section, may develop tensile stress in the base at the lower extremity of the assumed section. But the weight of the triangular mass of masonry on the downstream side of the same section and tangential forces together tend to cause rotation in the opposite direction. If the resultant of these forces acting downwards be of greater value than the resultant of the upward forces, it is evident that compression and not tension must be developed in the masonry. On the other hand, if the resultant of the upward forces be greater than that of the downward forces, tension will be developed, and the dam may fail along the line of the assumed vertical section.

So far there is no reason for finding fault with the proposition made by Mr. Atcherley. But when dealing with the actual distribution of tangential or shearing forces along the base, his reasoning is not so clear, and as no account is taken of the effects due to the fixing, or partial fixing, of masonry dams at the base, his conclusions must be accepted with considerable reserve. If a masonry dam merely rested upon a horizontal foundation and were prevented from sliding by friction only, Mr. Atcherley's hypothesis would be more tenable. As, however, the base is invariably let into the solid rock, the risk of tensile stress along the bottom is by no means probable.

No case can be cited of a dam which has failed along a vertical plane, and the only practical support for the new hypothesis is that afforded by experiments with small wooden models representing a dam actually built. The results of these experiments are said to show that the factor of safety against vertical failure is not more than two-thirds that against horizontal failure. Such models, not representing the actual conditions found in practice, could scarcely give results that are generally applicable, or that have more than academic interest.

Although this paper affords no justification for the idea that the Aswan dam is in any way unsafe, or for the belief that its height cannot be increased, we are sure that all engineers must feel grateful to Mr. Atcherley for his contribution, which has already had the effect of calling attention to a most interesting point that is clearly deserving of further investigation.

Mechanical Construction of Steam Turbines and Turbo-Generators.*

W. J. A. London.

The bedplates of large turbo-generators should be of some moderately in-elastic body, such as concrete, or brick and cement, and should extend the whole length of the turbine bedplate. Steel or iron constructions in foundations are not to be recommended, as they invite trouble, due to vibration.

In the Parsons and Westinghouse turbines expansion takes place in the revolving blades as well as in the stationary blades. This calls for fine radial clearances. With a drum type of spindle the loss by radial clearance space is somewhat larger than is the case with a disc type of machine, but skin friction is reduced to a minimum, there being no big areas revolving in media of different densities.

Owing to the difference of pressure between the two sides of the rotating vanes in a Parsons turbine, the whole annulus must be filled with steam so that small diameters and low velocities have to be resorted to where its density is very high, in order that the percentage of clearance to blade height will not be excessive. As the steam expands, its volume increases, and as the number of rows or blades varies with the square of the velocity, it is advantageous to step up in the diameter of the spindle as soon as possible. Various designs have been tried for these spindles, one type being shown in Fig. 1A, which consists of a plain forged steel drum having ends pressed into it of high carbon, or nickel steel. The steps are taken care of by a series of cast-steel rings. This type of spindle has the advantage that the forged steel body in itself is more homogeneous than the casting, and consequently is less likely to cause balancing troubles. The cast-steel rings can each be separately balanced and shrunk on. The disadvantage of this type is the number of parts necessary to make the whole, and the amount of machining and fitting necessary, which makes this construction somewhat expensive. Messrs. Parsons now use the type of spindle shown in Fig. 1B for all their designs, using cast steel for the drum. With spindles of this design balancing troubles are often very serious, it being impossible to guarantee absolutely homogeneous material, and on account of the weakest section falling midway between the bearings whipping is likely to occur, due to unbalanced mass.

The design of the stationary part of a Parsons turbine is a very important item, especially with large machines. As the diameters increase the greater is the tendency for distortion. Further, the cylinder cannot readily be supported between the bearings, owing to the fact that the centre part of the cylinder is at a higher temperature than the two ends, and the consequence would be that the cylinder would lift in the centre; this is exactly what must not take place. Further, any support or irregularity cast on to the part of the cylinder that must remain concentric at once causes distortion, and makes the cylinder elliptical or otherwise out of truth. It is, therefore, clear then that no rigid supports can be placed in the cylinder between the bearings. If ribs are necessary for stiffening on the under half they should be duplicated on the top half.

The British Westinghouse Co., between two and three years ago, when entering the field of turbine manufacture, arrived at the conclusion that the most successful turbine should combine the principles of action and re-action.

* Abstract of a paper read before the Manchester Local Section of the Institution of Electrical Engineeers on February 28th.

FIG. 1.—CONSTRUCTION OF TURBINE SHAFTS.

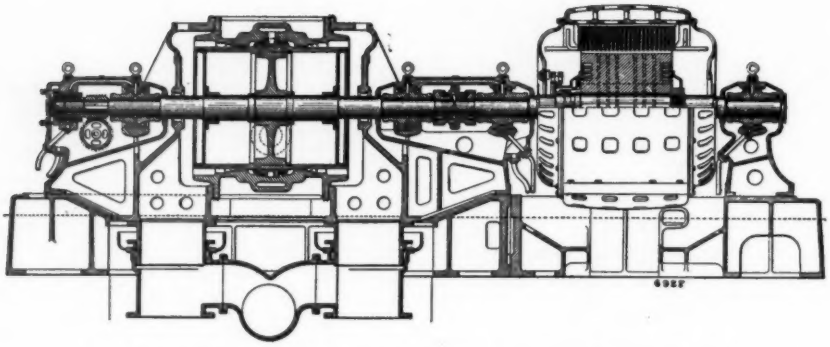


FIG 2. LONGITUDINAL SECTION THROUGH A BRITISH WESTINGHOUSE TURBO-GENERATOR.

The objections to building turbines on the straight Parsons principles lay in the great overall length, mechanical difficulties in the construction of the spindle, and the adoption of dummy packing rings to eliminate end thrust. By making the turbine double flow —that is, by admitting steam in the centre and passing same through equal rows of blades on each side—end thrust and dummies were eliminated, although the overall length of the machine become much greater than that of a straight Parsons turbine; further, the initial blade height would only be half the length of a single flow. This limiting blade height again would necessitate the stepping of the spindle.

In expanding steam from 160 lb. abs. to 27 in. of vacuum, the available work in heat units is 325 per lb., in expanding from 160 lb. down to 60 lb. abs. the available work is 78·9 B.Th.U., or about 24 per cent. of the total work in the whole expansion. In view of this it was considered that a slight decrease in efficiency might be allowed in the high-pressure end of the turbine if considerable mechanical improvements could be effected thereby. By adopting a combined impulse wheel for the expansion from boiler pressure to about 60 lb. abs., it was found that the velocity necessary for the wheel fixed such a diameter that Parsons blading could be successfully used on the one diameter already determined by the velocity of the impulse wheels. The specific volume of the steam at 60 lb. pressure was so much increased from boiler pressure that the initial blade height on a large diameter was not prohibitive. The result of this combination is that a machine can be built which is very much shorter than the Parsons machine for given conditions at the same time maintaining the high degree of efficiency. With this type of machine skin friction of the discs of the ordinary impulse type of machine is eliminated. The efficiency of the compound impulse section is comparatively high, but perhaps not so great as the remainder of the machine; this again is probably balanced by the losses due to skin friction in the long high-pressure end of the Parsons machine.

A longitudinal section of a British Westinghouse turbine is shown in Fig. 2, and the design allows of forged steel being used throughout in the construction of the rotating members. A centre shaft of high carbon steel extends from one bearing to the other, on which is shrunk the disc supporting the blade carrying drum. The centre disc is of forged steel, and the outer drum is of weldless rolled steel. This outer drum carries the impulse blades in steel rings which are shrunk on. The Parsons blading is carried directly in grooves in the main drum. Stiffening discs of thin steel are also fitted into the ends of the drum. A spindle of this construction is extremely stiff, and having a through-going shaft there are no joints in the spindle likely to give way and cause trouble. The stresses due to centrifugal force in a reasonably thin drum can be reduced mathematically to the following simple equation:—$C = MV^2$, where C = centrifugal force, M = mass of material, V = mean velocity in feet per second.

A further simplification of this formula, which, when considering steel or other material of similar density, is near enough for rough calculations only, is $C_1 = V^2/10$, C_1 in this case being the stress per square inch. The radius has no effect on the centrifugal stresses (other than loading by the blading),

and the peripheral velocity is, therefore, the limiting feature.

Special construction of the generator is necessary to cope with the speeds demanded by this class of prime mover. The majority of continuous-current generators to-day are constructed with semi-enclosed slots, a key-piece being driven in on top of conductors. This construction is satisfactory for the core of the armature, but the end windings require some other method of support. Fig. 3A shows one method of end winding with binding wire. This construction, as will be seen, is so designed that where the heaviest load comes on the conductors the thickness of binding wire is greatest. The alternative to the above construction, now generally used, is shown in Fig. 3B, the end winding being kept in position by bronze end bells. This construction has the advantage that repairs can be readily attended to. The greatest difficulty so far that has been experienced with this class of end bell is the procuring of suitable material. With cast bronze it is difficult to ensure the material being homogeneous; and, further, the physical properties are never so sure in this class of material as in the case of binding wire or forged material; so that, in a construction of this kind for the end bells, it is advisable, where possible, to use rolled material.

The form of commutator now adopted in nearly all continuous-current turbo-generators follows the line shown in Fig. 4.

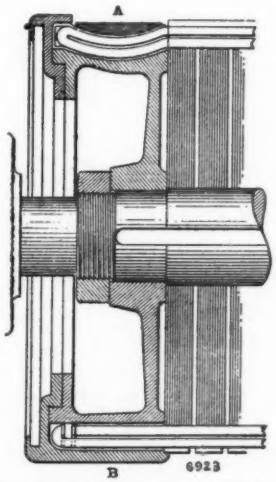


FIG. 3.—METHODS OF SECURING THE END CONNECTIONS OF ARMATURE WINDINGS.

The method of building up this commutator is as follows: The segments are built up with intervening layers of mica and clamped together. The mica is then tied round the outside at the place where the shrink rings are to be fitted, the steel rings then shrunk on and the whole machined inside and out. The commutator is then supported on cones at each end, which fit tightly on to the shaft. Owing to the wear that is bound to take place on such commutators, allowance must be made so that when the commutator is worn down to a certain extent, the segments do not become too weak to support themselves between the rings, and, in consequence, bulge out, causing high bars. To eliminate this a good scheme is to design the bars so that at, say, half the original depth, they are stiff enough to carry themselves rigidly, and have sufficient cross-section to carry the current without undue heating. In order that it may become apparent when it is time to stop truing up the commutator, a series of notches or grooves can be placed along the commutator segments indicating the limits for truing up. All overhanging mica, &c., should be turned off, as this has often been found to give trouble by collecting dirt. Everything throughout should be so designed that when running there is as little unbalanced mass as possible, and where keyways are cut in the shaft, two should be provided diametrically opposite, in order to keep the shaft itself as uniform as possible. Provision should be made in all armatures for the speedy application of balance weights.

It has been found that it is almost impossible to use carbon brushes on turbo-generators, owing to the fact that the armature floats when running, thus causing the brushes to dance. Metal brushes must, therefore, always be used, and, in consequence, unless commutating poles or compensating windings are adopted, the position of the brushes must be altered to suit small

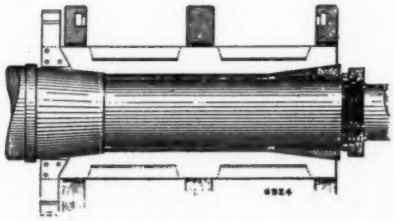


FIG. 4.—COMMUTATOR FOR TUREO-GENERATOR.

variations of the load. In all modern turbo-generators commutating poles or compensating windings are adopted, thus ensuring fixed lead.

During the last few years the demand for large turbo alternators for high voltages has necessitated the adoption of the rotating field type of alternator. The rotating field may be built up of (1) laminated plates; (2) slabs of forged steel, say, about 2 in. or 3 in. thick; (3) solid core with poles bolted on; (4) one solid piece.

All the above constructions are now adopted by different makers. In large machines the peripheral velocity amounts to something like 300 ft. per second. The British Westinghouse Co in their design for the 5,500 kw. turbo-alternators for the London Underground Railway Co. adopted the solid construction. These rotors run at 1,000 revs. per minute. The outside diameter is 67⅝ in., and the peripheral velocity of the pole faces 294 ft. per second. The field itself is a solid forging of Whitworth fluid-compressed steel, the centre being bored out to admit the high carbon steel shaft. The sides of the poles are milled out to admit the windings, ventilating ducts being also milled out. The solid pole construction materially stiffens the shaft, and, as the whole length of the poles themselves can be taken as being absolutely rigid, the only deflection that takes place is between the ends of the poles and the bearings. To reduce as low as possible the loss by windage smooth cores should be adopted where possible. In order to obtain ample ventilation two totally different methods may be adopted: (1) As much exposed surface and free air way as possible; (2) machine entirely enclosed with forced ventilation.

Both these systems are now extensively used, and it is hard to decide which is preferable. The first has the advantage of being more efficient, but has the objection of being noisy. This noise is almost entirely eliminated in the enclosed machine, but tests have shown that, with this type, to obtain sufficient ventilation, a considerable amount of power is absorbed by the blowers, resulting in a somewhat less efficient machine.

In turbine bearings we are confronted with the following conflicting conditions: On the one hand, the shaft should be sufficiently strong and rigid, necessitating large diameter journals, and the bearings must be sufficiently long to keep the pressure per square inch low, to allow of the oil being constantly renewed round the journal. On the other hand, the circumferential speed of the journal must be kept as low as possible to reduce friction. In order to make the whole length of the bearing effective, this length must not be excessive. For small turbines and generators with high speeds down to about 2,000 revs. per minute, the bearing almost universally used consists of a series of concentric tubes fitting loosely over one another, the intervening cylindrical spaces being filled with oil. For large machines, however, with speeds below that mentioned, the rotating elements can be sufficiently well balanced to run smoothly in solid bearings. The small bearings referred to are invariably of bronze, but with solid bearings, cast iron, white metal lined, have shown themselves to give excellent results. Even with large bearings for the comparatively slower speeds the bearings must be allowed a certain amount of give: this can be done either by easing off the bushes towards the end or fitting the whole bearing into a spherical seat. With white metal bearings the danger, of course, lies in their running out should the oil supply at any time fail. With bronze bearings the effect would be very severe seizing of the shaft, doing possibly a considerable amount of damage to the whole spindle. With good white metal bearings the writer has seen the oil supply fail, the only result being a slight wearing of the bush, causing no damage whatever to the shaft. As regards the metal for the journal itself, the experiments of Herr O. Lasche, of Berlin, go to prove that the metal employed, whether of nickel steel, Siemens-Martin steel or mild steel, has little influence on the degree of friction. With regard to the degree of smoothness and to the facility for taking a highly-polished surface, Herr Lasche points out that miscroscopic examinations of the outside faces, even with magnifications of 100 times, did not reveal any great difference in their structure. The coefficient of friction for mild steel was found to lie between those of the harder materials, Siemens-Martin and nickel steel. The experiments clearly show that there is no great gain by using nickel steel. Further, the nickel steel, after a somewhat prolonged service, showed larger pores than a mild steel journal of equal service. The effect of clearance has a marked influence on the efficient working of turbine bearings. It also has a large influence on the amount of total friction, and also on the running and safe working conditions. In bearings with small clearances a relatively great amount of power is required to overcome the friction, even if the shaft is not very heavily loaded. Friction between the shaft and the oil, between the oil and the bushes, and between the oil

particles themselves has to be overcome. In consequence it is better to ease the bearings considerably on the upper half; this materially decreases the friction and allows much smoother running. If the shaft is well balanced the upper half of the bearing can be entirely dispensed with, and this is practically done in many instances, a clearance of $\frac{1}{16}$ in. being allowed on the top half of the bearings. However, should the shaft have any tendency to whip, an uncovered bearing of this kind leads to trouble, as it offers no resistance to the shaft moving laterally. For this reason instead of cutting the whole of the top of the bearing away it is safer to allow a strip of the bearing to remain along the top, thus holding the whole shaft.

The peripheral velocity in turbine bearings is necessarily very considerably higher than in ordinary steam-engine practice, velocities of 50 ft. per second being regular practice. The load per square inch, however, must be kept very low. In steam turbine practice to-day it is usual to allow a constant of 2,500 for the peripheral velocity in feet per second multiplied by the pressure per square inch on the bearings. This in some cases is raised as high as 3,000. Experimental bearings have been run, however, with a peripheral velocity of 70 ft. per second and a pressure of 70 lb. per square inch, thus giving a figure of 4,900. The crux of the whole question is the facility for dissipating the heat, and for this reason as much of the bearing as possible should be in contact with the outer walls, provided, of course, that the outer walls themselves are also free to dissipate heat. Water-cooled bearings are very often resorted to in very large machines, the principal advantage of these being that in a turbine of the Parsons type the heat from the high-pressure end of the turbine is transmitted to the bearing, the water-cooled bearing, therefore, isolates this heat from the bearing proper. In machines where there is no close contact with steam-heated surfaces, the bearings working within the limits mentioned—viz., from 2,500 to 3,000 for p.v. can run satisfactorily without water cooling. An ample oil supply, however, should be given; in fact, the supply of oil in turbine bearings should not be restricted. In steam turbines the oil leaves the bearings uncontaminated by water or other matter, and can be returned to the cistern and re-used, so that there is little loss by providing an ample oil supply. The usual European practice in turbine work is to allow about 0·05 gallons per square inch of bearing surface per minute. Ball bearings at moderate speeds give excellent results, but they do not stand the test of high speeds; they are noisy even with small balls. This is very pronounced when the peripheral velocity of the revolving body is about 30 ft. per second, so that on the whole they are not suitable for high speed work, nor are they as safe as the plain bearing.

To reduce the troubles arising from imperfect balancing to a minimum, the following points must be taken into consideration in the design of the machine:—(1) The materials adopted should be as homogeneous as possible. (2) The design should be absolutely symmetrical. (3) Where possible all parts should be machined inside and out with the greatest accuracy. (4) The shaft must be sufficiently stiff to resist undue whipping. (5) Special care must be taken with the windings and insulations to ensure rigidity when running. (6) Where possible the normal running speed should be below the "critical speed." If this is not possible the normal speed should be reasonably higher, so that the critical speed, except when running up or shutting down, is never reached in ordinary operation.

Where possible forged steel should be used throughout in the construction of the rotor; if this is adhered to considerably less trouble is likely to present itself than would be the case were castings used. In connection with the design of a shaft of sufficient strength to resist whipping, the length between the bearings should be kept down to a minimum. This length, however, is determined by the maximum peripheral velocity allowable on the rotor. With turbine spindles of the Parsons type the ratio of the length between centres of bearings to the diameter at the centre of the shaft is often as high as 11, and in small generators 6 to 8. It is often necessary, therefore, to apply balance weights at, or about, the centre as well as at the ends before smooth running can be accomplished. In continuous-current machines provision is therefore often made for applying balance weights to the inside ring of the commutator (Fig. 4). With rotors for 1,000 kw. generators and upwards, this ratio rarely exceeds three, and in the majority of cases in very big machines about 2·5. With this ratio balancing troubles, with the reasonably low speeds now adopted, are never very serious. One of the greatest troubles experienced in maintaining good balance of turbo-generators is due to the shifting of the conductors. This often happens after the machine has been running some time, and as the insulation dries it gets compressed by the centrifugal force on the conductors. The slightest

shifting of these conductors is likely to throw a big rotor considerably out of balance. Should the machine at one time or another run away and attain the speed of, say 1½ times the normal running speed, the severe load resulting is often sufficient to throw the whole rotor out of balance. In all bodies revolving at high speeds there is a period at which excessive vibration will take place, and is called the "critical or whirling" speed. It coincides with a point at which the natural period of transverse vibration of the shaft loaded with the rotating element is equal to the impulses given to the shaft by the centrifugal force acting on a slightly bent shaft; at this speed steady operation of the shaft is impossible. Mathematical investigations of this phenomenon have been carried out and published by Prof. Dunkerly and others.

The critical speed for any shaft is given by Foster as:—$N = 9{\cdot}55\sqrt{Fg/W}$, in which W = weight of rotating mass and a portion of the shaft, and F = force in pounds weight necessary to bend the shaft 1 ft. at the point of attachment of the wheel.

The above formula is for a shaft of diameter D feet.

Then $F = 3EI(a+b)/a^2b^2$, in which E = modulus of direct elasticity in pounds per square foot; I = moment of inertia of the cross section $= 0{\cdot}0482D^4$; and a and b = distances in feet of the wheel from the bearings.

The following formula is given by Behrend for turbo-generators:— $N_1 = \sqrt{KEI/ML^3}$. In this case N_1 is the angular velocity at critical speed, E = modulus of elasticity, I = moment of inertia of the shaft in relation to bending, M = mass of rotating element, L = distance between bearings, K = constant whose value is about Z_5.

Where possible in the construction of rotating parts for turbo-generators static balance of the respective parts should always be resorted to before being run; although, of course, it does not necessarily follow that, if it shows perfect balance on the knife edges, it will be correctly balanced when running. In balancing, if the rotor is considerably out of balance, one is very often much tempted to apply considerably more weight than is necessary. If the weights are applied at the periphery of the body, which has a velocity of, say, 300 ft. per second at a radius of 1 ft. the actual weight applied is multiplied by the centrifugal force 3,000 times. Very small weights, therefore, have considerable effect in throwing the whole body back into balance.

Coolgardie Water Supply.*

C. S. R. PALMER, M.Inst.C.E.

THE elevated tract of country situated in the interior of Western Australia, and known comprehensively as the Coolgardie Goldfields, is exceedingly arid, fresh water being unobtainable naturally, and only in small quantities by conservation, while condensed water is very expensive. The first real impetus to the progress of the Colony was given by the discovery of gold at Coolgardie in 1892, and thereafter not only mining, but also the agricultural and pastoral industries rapidly increased, and it was realised that help given to the first-mentioned must also aid the latter. Large expenditure was first incurred on small local water-supply works, but without commensurate results, and the Government decided on a comprehensive scheme of construction.

After inquiry into alternatives, it was recommended that the work should consist of a storage-reservior in the Darling ranges (capacity 4,600 million gallons, enough for two years' supply and loss), a 30-in. pipe to carry thence five million gallons daily, a series of pumping-stations along the pipe-line, and service reservoirs at various centres; the estimated cost of these works being £2,500,000.

Parliament having approved the project and provided funds, an English Commission of engineers was appointed to report on the proposals and advise on the design of the pipes, etc. Work was started soon after receipt of their report, which generally confirmed the original outline scheme. Five years afterwards, in January, 1903, the works were formally opened, and they have supplied water continuously since.

The reservoir dam or weir is built across the Helena River, the height of the crest above river-bed being 110 ft.; and the storage is sufficient to provide two years' consumption and loss. The catchment-area is 569 square miles, but the rainfall comparatively is small, and the off-flow low. The author details the rainfall and off-flow, and argues from the figures that percentage estimates are liable to mislead in some cases. The reservoir-basin is described as badly crossed by volcanic dykes, but these are water-tight, as the small loss from the reservoir proves. Analyses are given of the water stored; they show it to be of good quality, but rather high in ammonia, higher at the reservoir than after the journey

* Proc. Inst. Civil Engineers, March 28th, 1905.

through 350 miles of pipe to the gold-fields. The surplus or flood waters pass over the whole length of the dam, thus forming probably the highest overflow weir constructed; and so far no damage has occurred.

A bad fissure was found in the rock foundations of the dam when opened up, necessitating excavation to 90 ft. below bed-level. The fissure was then bored into, and the water-tightness of the material was tested before concreting commenced. The author describes the section of the weir, the water-cushion, the valve-towers and the draw-off arrangements, and he states that the whole have acted satisfactorily, and that the rainfall has proved ample to satisfy the requirements.

The dam is built of concrete, and as nothing but stone was available locally, a branch line of railway 4¼ miles long, was built to convey cement, sand, etc. Water for the works and for the workmen was obtained by constructing a subsidiary weir up-stream, and the small reservoir (20 million gallons capacity) thus formed, with its overflow channel and flume, dealt with all but a few extreme floods, thereby facilitating work on the main dam. The cement used was very carefully tested, not only to ensure none but good material being used, but also, as the source of supply was so far distant, to ascertain what local treatment would render good such cement as heated excessively when setting. The results of analyses and of tests of tensile strength, fineness, and heating, are detailed, and attention is drawn to exceptional behaviour.

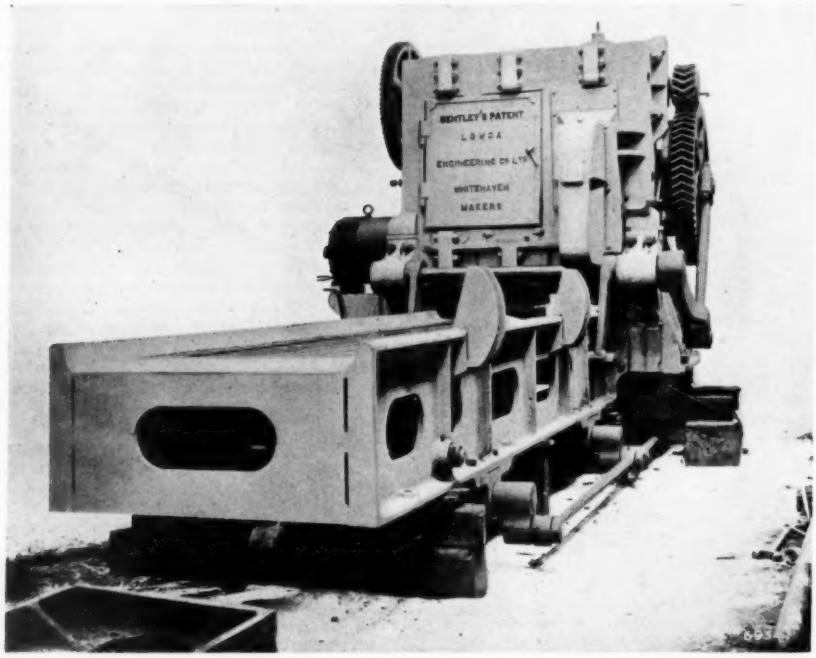
The sand was all washed before use, the stone was quarried and broken locally; raw materials deposited near the mixer were worked down as much as possible by gravity, and the mixture was similarly helped in transport to the weir. Excavation of foundations was carried on night and day, an electric installation furnishing light. The concrete was spread and rammed by hand, bond being broken and plums introduced for greater cohesion and shearing resistance between layer. The concrete was built between timber frames, the mixture next the boards being worked smooth with straight spades to save rendering.

The English commissioners before mentioned were asked to report specially regarding the pipes, and the points remitted, and the information furnished to them, are stated by the author. The commissioners recommended that of the pipes three-fourths should be riveted and one-fourth welded, that expansion-joints should be used, and the pipes be laid above ground. Tenders were invited accordingly, but permitting of alternative offers, and in the result a new form of pipe—the locking-bar pipe—was accepted, being cheaper than welded pipe and, strength for strength, than riveted pipe. The saving on the estimate enabled thicker pipes to be used, and the danger of undetected leakage from riveted pipes being removed, the main was laid below ground with ordinary lead joints. Analyses are furnished of the soils along the pipe-line. For reasons given, the protective coating consisted of one part of asphalt and one part of coal-tar. The leakage from the main, both when first filled and also in regular working, was found to be small. Drawings and explanations are furnished of valves, specials, and special works connected with the main.

The author next describes the locking-bar pipe, giving the relative weights and strength of steel required for plates and bars to obtain uniform strength, and he supports his opinion by the results of tests. He also explains the method of manufacturing and coating the pipes. Careful tests having shown that machine-caulked joints should prove more uniform than handwork, a machine patented locally was employed, and this, together with the method of its use, is explained. When work was in full swing, as much as 35 miles of pipe per month were caulked with seven machines, at a cost no greater than that of handwork, and with small resulting leakage. The sequence and method of the operations of laying and charging the main are described. No bursts occurred, but six cases occurred of pipes being cut through by the combined action of sand and water.

The friction-head allowed for in the power-calculations was for dirty pipes, and adding natural head the total lift was calculated to be 2,655 ft.; but to provide for identical pumping-sets, 2,700 ft., in four lifts of 450 ft. and four of 225 ft. was arranged for. Results of tests of actual friction-head made on laying the main are given; also the working and reserve power, the cost of the machinery, the tests provided in the contract, and the results obtained.

These reservoirs are of concrete, and consist of six of 1 million gallons each for pump suction, two of ½ million gallons for regulation of flow in the main, and one of 1 million, one of 2 million, and one of 12 million gallons for service purposes. Drawings are given typical of all but the last, which is of separate design. Its concrete lining



PATENT PIG-IRON BREAKING AND LOADING MACHINE.

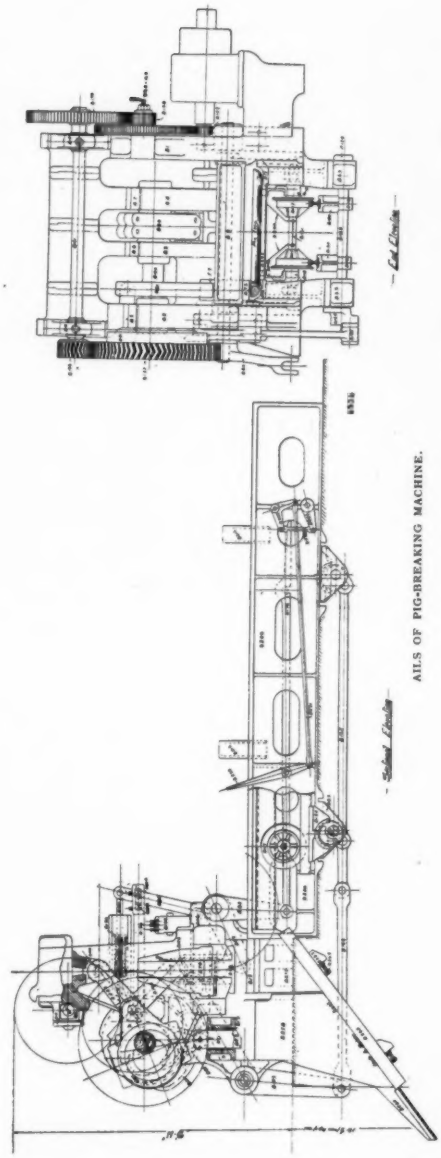
is thin, unbacked, and built in sections, with expansion joints filled with bitumen between sections. A grillage of barbed wire in each section keeps it intact, and the joints are easily caulked when necessary. Normal sand being too expensive, a fine loamy sand was used for the concrete of the large service reservoir, with good results. The original scheme did not provide for reticulation of townships, but this was eventually carried out at Coolgardie, Kalgoorlie, Boulder, and the Kalgoorlie mining belt. A telephone line, 380 miles long, connects headquarters, the pumping-stations, and the service- and regulating-reservoirs with each other.

The author, who succeeded the late Mr. C. Y. O'Connor, M.Inst.C.E., was responsible for half the work. The original estimate, deducting the cost of work not carried out, amounted to £2,435,000, and the actual cost to £2,660,000, the excess being fully accounted for by the extra expenditure in providing high-duty pumping machinery.

Pig Breaking Plant.

THE subject of the accompanying illustrations is a plant for handling and breaking pig iron without resource to manual labour, and by which the "pig lifter" is dispensed with and the labour charges at the blast furnaces reduced. It is built by the Lowca Engineering Co., Lim., of Whitehaven, and lifts, breaks, and loads into wagons the pig from one or any number of furnaces without manual labour, the services only of machine attendants being required. As the new plant can be adapted to any situation, no alteration to existing pig beds or casting arrangements is involved.

As will be seen, the plant consists of the patent breaker, and an overhead or jib crane, both of which may be driven electrically or by steam. The method of operation is as follows. The pig iron is lifted by the crane out of the sand in complete "combs" or "beds," as shown in Fig. 3, and conveyed to the table of the breaker. The comb having been placed on the machine, a feed



AILS OF PIG-BREAKING MACHINE.

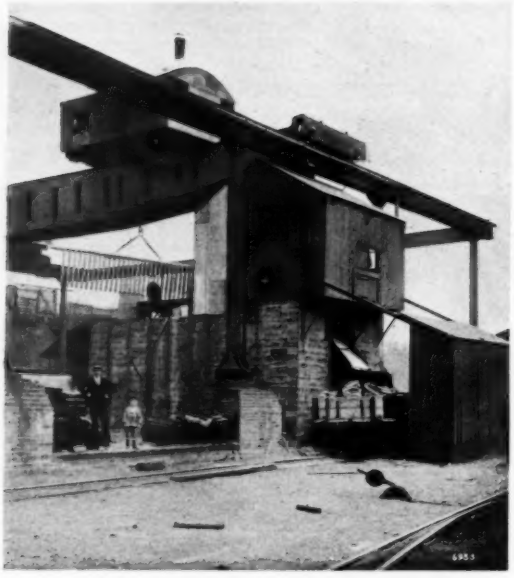
table, reciprocating between the frames, is raised by eccentrics and is held up in this position until the table has travelled the required distance to bring the pigs under the ram. The table is then automatically lowered, thus leaving the comb on the fixed frames. The pigs being now placed on the breaking blocks, a wedge block descends and grips the sow, while a ram comes down and breaks three pigs. Following the ram is the sow ram, which breaks off the required length from the sow. The wedge block is then raised, during which operation the table is carried back into its former position, ready for another set of pigs, when the action is repeated. A handle is placed on one side of the fixed frame for disconnecting the table after completion of one bed while another bed is being deposited upon the table. It is then put into gear, and the cycle of operations repeated.

All the working parts are specially protected to prevent the sand blowing into them. The broken pigs are then automatically discharged from the machine into railway wagons ready for delivery.

The machine has great strength and durability, and can deal with quantities of pig iron up to 100 tons per hour. The labour costs for lifting, breaking, and loading into wagons, while varying according to local circumstances, may be taken as being about 1¼*d.* per ton. One attendant is required for the crane and another for the breaker, while one labourer is employed on the pig bed hooking the crane chain to the combs, and another labourer putting the wagons under the shoot of breaker and generally supervising the loading. As the pigs are not broken on the pig beds no scrap is made, and this usual loss is avoided. The moving of the empty wagons to, and the loaded ones away from the breaker, is much facilitated when the sidings are laid at a gradient of about 1 in 75.

While this is descriptive of the standard type of machine, it should be noted that it can be very readily adapted, so that instead of breaking the pigs into small pieces, they can be broken off in one length from the sow, and the sow can be broken off the same length as the pigs themselves. Arrangements are also provided on the machine so that it will automatically deliver the broken sow or pigs in their original length to specially constructed wagons in such a manner that sling chains can be easily passed round the bulk for loading purposes.

While appreciating the value of the machine for breaking Bessemer iron into



PIG-BREAKING BUILDING.

the usual small pieces, ironmasters producing basic and Cleveland iron have contended that the machine is not exactly suitable for breaking pigs whole. It will be seen that the machine is now arranged for this purpose, and the makers claim that a considerable saving is effected over and above the old methods of lifting and breaking by hand.

Wood Gas for Power Purposes and Gas Generators.*

GEO. M. DOUGLAS.

THE concentrating works and mine of the Moctezuma Copper Co., located at Nacozari, Sonora, Mexico, are operated by electric power distributed from a central power station.

This power-house contains ten gas engines of Crossley's "Otto" type; belt connected to dynamos generating direct current at 260 volts. This is distributed direct to the mill and other motors about the concentrating plant.

The mine is six miles distant from the power-house, and current is supplied from a motor-driven generator, giving at 6,600 volts 3-phase alternating current of 25 cycles. At the mine this 6,600 volt current is "stepped down" by transformers to 230 volts. Pumps, &c. are operated from this low tension alternating current, but for the mine hoist and electric locomotive it is converted to 250 volt direct current by a rotary convertor.

The gas is supplied to the engines from a Loomis-Pettibone gas generating plant in which the method of operations is slightly modified from the original practice of its makers.

This gas plant consists of two duplicate sets, in each of which are two generators and a boiler. A wet scrubber and exhauster, Root's positive pressure type, are common to both sets.

These generators are steel cylinders, fire-brick lined, of 9 ft. external and 6 ft. 9 in. internal diameter. The grates are about 3 ft. above the bottom, and the height of the generator permits of a fire of about 8 ft. in depth on the grates. The grates are made of fire-brick arches, forming a dome with 6 ft. radius. There is a door on top, which is used for feeding fuel and for admission of air. The generators are connected by 12 in. pipes just below these top doors and above the maximum height of fires.

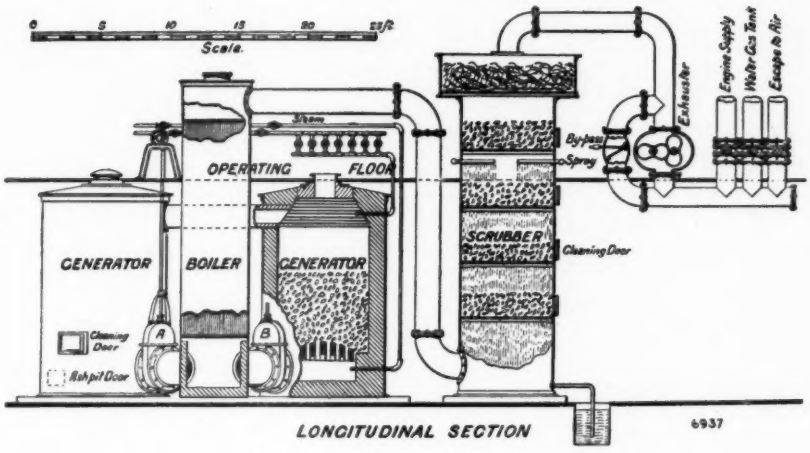
Below the grates the passage of gas is through 33 in. brick-lined pipes to a common chamber below the boiler. In these pipes are gate valves, water-cooled externally, referred to later as A and B.

There are also three 12 in. by 18 in. cleaning doors in each generator. These are used only for cleaning ashes from the generators when they are not in operation.

The generators, boiler and scrubber are on the suction side of the Root's positive pressure blower mentioned before. From a header on boiler four 1½ in. pipes lead, one above the maximum height of fires and one below the grates on each generator. These are controlled by valves on the feed floor.

The fuel fed through the top doors forms a charge from the top of which the volatile gases are distilled. The air passes through the same door as the fuel, and partial combustion of the volatile gases and fixed carbon of fuel supplies heat to the charge. The partial combustion of hydro-carbons takes place near the top, and that of the fixed carbons lower in the charge. No unfixed

* Paper read before the Institution of Mining and Metallurgy, April 13th, 1905.



LOOMIS-PETTIBONE GAS GENERATING PLANT.

gases pass through the incandescent lower part of a charge.

These gases pass through the grates of the generators up into the boiler and thence to the bottom of the scrubber. The scrubber is a cylindrical vessel, on which four or five trays, filled to a depth of 2 ft. with coke, are placed 4 ft. apart. A sprinkler is provided above the top tray, which distributes water at a rate of 3,500 gallons per hour. This passes from one tray to another in an even shower, and on meeting the gases on their upward passage cleans them free of fine ash and finely divided fixed carbon.

The gases enter the scrubber at a rather lower temperature than the gases in an ordinary steam boiler, uptake and leave at about atmospheric temperature.

The water used in the scrubber may be passed over cooling tower and used again, only deficiencies due to evaporation being supplied. If water is plentiful, a continuous stream of clean water is better. On top of the scrubber and over the sprinkler is a "header" of larger diameter than the scrubber, filled with "excelsior" wood shavings, which act as a final absorbent of soot before the gas passes to the exhauster. It may be mentioned here that the above arrangement for cleaning gas is not sufficient when using a volatile fuel such as wood or soft coal. A dry scrubber with "excelsior" or oily waste between exhauster and tank would be a decided advantage.

On the suction side of the exhauster the resistance of the charge to draught through it and the scrubber, varies from 4 in. or 5 in. water pressure with new fires, to 24 in. or 28 in. with old. This depends on the kind of fuel used, amount of gas made, and conditions of fires.

The discharge of the exhauster leads to a header from which three pipes are taken, controlled by gate valves. These lead to a large tank for engine supply, weighted to 5 in. water pressure, a small tank weighted to 8 in. water pressure, in which water-gas may be separately stored, and an open pipe to the air.

From the top of the boilers is an 8-in. pipe leading to the suction of a Sturtevant blower. This is used to supply draught when starting fires; for even where it is possible to do so, it is objectionable to use the exhauster for this purpose, as in the cold fuel bed no decomposition of volatile gases takes place which would cause trouble in pipes, valves and exhauster by condensation of tar.

The wood fuel used at the Nacozari plant consists mostly of an inferior scrubby oak. A little "mesquite" is used, and another species of oak locally called "black" oak. This latter is the best. It is supplied from neighbouring hills and is brought to the plant in 3 ft. 6 in. lengths. These are sawn in two with a swing saw.

In starting and operating this plant with such wood for fuel, the method that four years' experience has shown to be best, is as follows:

Coke is put on the grates of the generators to a depth of 3 ft. to 3½ ft. Less than 3 ft.

is not advisable when making gas from wood, otherwise volatile products of distillation from the fuel may pass through unfixed, and by condensing to soot or tar may waste fuel and cause trouble by dirt.

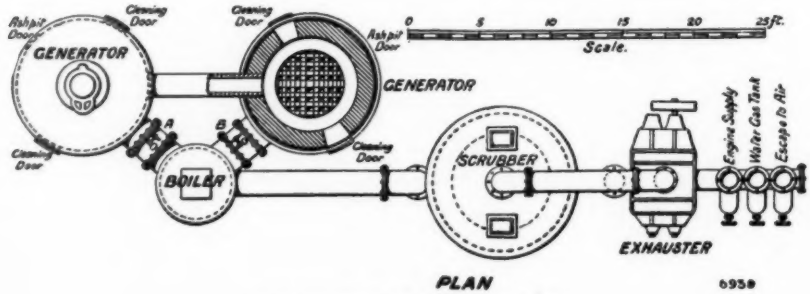
The writer has had no experience with wood running high in volatile matter, such as pine, but it is probable that in the case of such woods a deeper coke bed would be preferable. Small and light wood, tops of trees, branches, etc., should be put on coke to a depth of 3 ft. or so, and the blower started. A handful of lighted oily waste thrown on top of the wood will start fires. The light wood is enough to make a coke bed incandescent and usually requires about an hour. As soon as this is seen to be the case, fast feeding with heavy wood is necessary. The heavy chunks which are objectionable when fires become older, are well saved for this purpose. The fires should be kept at a low temperature, which may be regulated by the speed of feeding. Only enough combustion is required to transform the wood into charcoal. When a bed of this incandescent charcoal and partly-consumed wood is formed to a depth of a couple of feet above coke bed, the fires are ready for supplying gas to the engines; the valve to suction of exhauster should be opened, the fan stopped and its suction valve closed.

This preliminary operation usually requires four to five hours in time, and 3½ to 4 tons of wood.

When changing from old fires to new, as is usually the case, both main valves may be left open, so that the exhauster will act on both sets of generators. Owing to low resistance offered by new fires, only enough air will pass through the old ones to completely gasify any fuel that may be left therein. They should be stirred occasionally with a bar during this "burning down" process, and the holes filled to keep the surface level. It is easily seen when all combustible matter at top of old fires has been consumed, by the peculiar bright appearance the ashes take. The top doors should be closed at this stage and a little steam let in to the generators from their top steam connections. This steam passes downwards through the fires, and by its decomposition a great deal of the heat in the old fires may be utilized. As the gas from the new fires is usually somewhat poorer the first two or three hours, this "water-gas," mixing with and enriching it, can most opportunely be taken advantage of.

It is neither desirable nor necessary to make water-gas on new fires until there has been at least four hours' run on them. Water-gas is made by closing the top doors on both generators and one of the gate valves between generator *A* and boiler, and opening a valve that is in a pipe acting as by-pass from the suction to the discharge of exhauster. This is done so that no risk is incurred of throwing an undue strain on exhauster or motor by its suction being closed. The exhauster being "by-passed" the steam pressure acts directly to fill the tank. Steam is turned on below the grate of the generator, the gate valve of which (*A*) is closed. Its only passage is upwards through the fire, across through the connecting pipe at top and downwards through the fire in generator *B*, through boiler, scrubber, etc., to tank. After not more than two minutes of this discharge from an open pipe 1½ in. diam., steam at 120 lb. pressure, the steam valve is shut, valve *A* is opened, valve *B* closed, and the operation repeated in the opposite direction, and, if anything, for less time.

In passing through the incandescent fuel, the steam is decomposed into its original constituents, hydrogen and oxygen, of which



LOOMIS-PETTIBONE GAS GENERATING PLANT.

the former passes through as fixed gas and the latter associates with the carbon of the fuel to make carbon monoxide.

The following is an average sample of this water-gas :—

H.	CO.	CH_4.	C_nH_{2n}.	CO_2.	O.	N.
52·77	10·08	2·9	0·63	20·76	0·13	12.72

The calorific value of this at 62° F. and at sea level is 240 British Thermal Units per cub. ft. When the plant was first started up, erroneous ideas were held, in that it was supposed a comparatively large amount of water-gas should be made and mixed with producer-gas. Following this idea led to some waste of fuel and considerable unsteadiness of power.

The making of water-gas directly, as by the method described, is essential only in that it loosens up fires and ensures free passage of air and gases through them. That gas of a higher heat value is made in doing so may be considered as incidental and taken advantage of for certain purposes, such as engine igniters, assay work, etc. If the consumption of water-gas for these purposes is not sufficient to make necessary a run of about 1,500 cub. ft. at not greater intervals than an hour, the water-gas should be mixed with producer-gas by means of the small pipe from one tank to another, regulated to bring consumption to desired amount. Making long runs of steam through the fires, alternating with periods of violent blasting, means uneconomical use of fuel and unsteady gas. Too much stress cannot be laid on the desirability of keeping the fires at as even a temperature as possible.

When using coal for fuel, the heat of fires and gas values may be regulated to a nicety by constant admission of steam through the top connections to mix with air before passing through the fuel bed.

With wood for fuel there is enough moisture present in the fuel itself to supply this steam for decomposition. When making gas at the rate of 1,100 cub. ft. per min. from 6 ft. 9 in. generators, experience shows best results are obtained from wood containing 12—14 per cent. moisture.

Burning wood at the rate of 30,000 lb. per diem, the ash accumulates, so that by the fifth day's run on one set of plant it is necessary to shut them down to clean, changing to other set as described, for operation.

For the first thirty-six hours the fires should be allowed to rise, *i.e.*, more wood should be put in than is consumed to ash. This becomes charcoal and adds steadiness to the value of the gas. There is no ultimate loss, all fuel in generators being recovered before shutting down to clean.

The wood should not be longer than 2 ft.; heavy chunks are objectionable and should be split: the size of the wood is a point to which attention must be paid, since using large and irregular-sized wood produces poor results. The heavy chunks that cannot be split easily should be reserved for starting fires and may be used to good advantage during the first 12 hours of the run. The fire should be fed steadily and a little all the time. Judicious use of different sizes of wood must be made by attendants to keep the surface of the fires level and ensure even passage of gases through them. The manual dexterity to place a stick of wood where it is at best advantage is an important thing to be acquired by the attendant.

This statement may be decried by some as trivial, but it will be found that success depends on the amount of attention paid to these trivialities. Bars or pokers should be used as little as possible except during the first six or eight hours on new fires, when the wood must be kept well raked out to the sides from the centre of fires. During the first twenty-four hours great care must be taken by the attendants to ensure the fires being evenly built up.

The following is a sample that may be taken as an average of the composition and calorific value of this wood-gas. It is the average of more than 15 tests taken at various times :

H.	CO.	CH_4.	C_nH_{2n}.	CO_2.	O.	N.
19·5	13·45	2·48	·34	15·45	·25	48·5

The calorific value in B. T. U. is 135·6 at 62° F., and sea level.

The above gas gives remarkably good results in the engines, and is better than gas from coal of the same calorific value, but in which the proportions of hydrogen and carbon monoxide are reversed. The writer can offer no reason why such should be the case, but it is demonstrated by practical experience. That hydrogen is a quicker burning gas than carbon monoxide may have something to do with it. The proportions of CO_2 and N are about 8 and 55 in coal-gas, compared to about 15 and 48, respectively, in wood-gas, which may have some effect on the charge, although they are both inert gases.

No trouble is experienced with pre-ignition, though the percentage of hydrogen in wood-gas occasionally runs up to 23 per cent., and the compression of engines is as

high as 90 lb., with pistons uncooled by water.

As all output is measured through one integrating watt-meter, and all fuel used has to pass over scales before entering the feed floor, and is checked up by R. R. weights as well, the figures from the Nacozari power plant offer exceptional accuracy.

A trial was made recently on one set of generators for a run in which the greatest care was taken to ensure accurate figures. There was no intention to make an exceptional showing; indeed, the conditions of fuel as regards moisture, and the fact that the output was only about two-thirds capacity, made the best showing out of the question. The transmission line was not in operation during this trial.

Fires were lighted in the set of generators and the trial was made at 9.30 a.m., on December 26th, 1904. At 3 p.m. they were ready to run on and the old fires were discontinued altogether at 7 p.m.

At 2 p.m., December 31st, after 4 days 23 hours' run, a change was made again and the trial completed.

The following is the output and fuel consumption:—

Coke put in generators	8,590 lb.
Wood used firing up	7,400 ,,
Duration of run.....	119 hours.
Total amount of ash taken from generators	14,124 lb.
Amount of coke recovered	2,572 ,,
Total amount of wood used	138,840 ,,
Total amount of coke used	5,918 ,,
Total amount of combustible ...	144,758 ,,
Percentage of water in wood ...	19·8%
Percentage of ash in wood	10·3 ,,
Calorific value of gas B. T. U. (actual) (Average of 35 tests made throughout trial)	116·4
Total output of Power = ...	39,700 kw. hours.
House = ...	53,217 hp. ,,
Average Power = 447·2 Electric hp.	
Consumption per Electric hp. hour = ...	2·6 lb. wood. 0·11 lb. coke.

Electrically-driven Street Watering Car.

For the past six months the municipal tramways of Cologne have been using an electrically-driven car travelling over the tram lines for the purpose of watering the streets. In order to overcome the nuisance caused by the dust raised by the tramcars, the city of Cologne found itself compelled to resort to a continuous watering of the roads through which they run. The acquisition of some extra water carts was thus rendered necessary, and the municipality resolved to consider the question whether it would not be better to water the streets by means of a car travelling upon the rails. Three solutions of the problem presented themselves:—(*a*) A separate watering cart drawn by a tramcar; (*b*) an independent car mounted on two axles; (*c*) an independen car mounted on two bogeys. The choice of a watering cart coupled to a car would have been the most advantageous solution from the point of view of the prime cost, the latter being only about £200, but this arrangement would have monopolised almost altogether the motor car to which the watering cart was attached. Since it was required that the roads should be watered on Sunday afternoons and on holidays, that is to say, at times when the passenger traffic was greatest, the tramcar would have to be withdrawn from the service when it could least be spared. It would, therefore, have been necessary to acquire a separate motor, and since the latter would have to be always in front of the watering car, to effect the manœuvres at the refilling stations special tramlines would have to be laid down. These circumstances led to the conclusion that a watering car coupled to a motor was not a very satisfactory solution. On the other hand, an independent watering car mounted upon two axles would have cost £540, but it would have been attended with a serious drawback. Since the load upon each axle must of necessity not be excessive, the reservoir could only have been given a relatively small capacity. Calculations made the tare of the car so great, that the supply of water carried would have to be reduced to not more than five cubic metres. Compared with the car mounted on bogeys, which would be capable of taking 10 cubic metres of water, the efficiency of that mounted on axles would have been not more than one-half, and besides the number of refilling stations would have had to be increased. If we consider that the cost of each of the latter, including the points and siding, amounts to about £160, it will be seen that the first outlay for the axle mounted cars would have been much the greatest. In addition to this the necessity of refilling the car more frequently would have also led to loss of time and diminished the output. The adoption of the bogey car was ultimately decided upon, notwithstanding the higher cost (about £720), since it appeared to offer the best solution of the problem. This car has, up to the present, given perfect satisfaction, and we have on

that account thought it would be of interest if we gave a concise description of the same.

The construction of the watering car. As shown in figure (1) the car consists of a water reservoir of a capacity of ten cubic metres mounted on a framework supported by two bogeys, each of which is driven by an electric motor of 35 h.p. The current is conducted to the latter by means of a hoop fitted upon the upper portion of the reservoir. The weight of the car when empty is about 13 tons, and with a full load about 23 tons. The water distributing devices consist of two pipes for sprinkling the road outside the tramlines, and of two others located one in front and one behind under the platforms for the purpose of watering the track. The latter are arranged at the end of the frame in such a manner that the dust becomes moistened before the passage of the car. The different jets enable the amount of the discharge as well as the area over which they operate to be regulated, so that the space between the tramlines can be watered alone if desired, or a large lateral zone on either side of the car can be included. The maximum width that can be sprinkled is from 15 to 16 metres, therefore by working on one side only it is possible to water a strip from 9 to 10 metres wide. The two pipes under the platforms in the front of the car are operated by means of pedals within easy reach of the driver, and the lateral jets are worked by means of levers fitted on the platforms, which enable the distance to be regulated. Each of the pipes under the platforms opens into a box furnished with two spring valves (Figs. 4 and 5) which feed the sprinkling apparatus. The latter is divided by means of a partition into two compartments, which are perforated with holes of different diameters. The intensity of the jet varies according as one or both of these compartments are utilised. The latter are in each case provided with a dashboard or baffle (Fig. 5), which causes the water to spread itself in a uniform manner over the perforated surface. The area sprinkled by the pipes under the platforms is 2·50 metres. The parts can be easily taken out and cleaned. A movable sieve, fitted at the inlet of the water into the pipes, stops any particles of sand or other substance that might stop up the holes. The arrangement shown in figs. 2 to 3 is utilised for the effecting the lateral discharges. It is mounted in the middle of the car, on either side of the reservoir, and

FIG. 1.—ELECTRICALLY-DRIVEN STREET WATERING CAR.

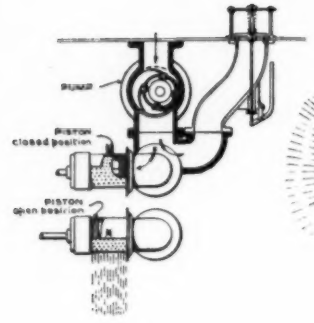


FIG. 3.

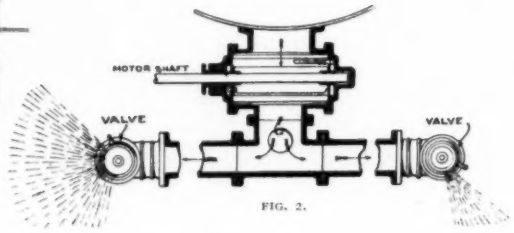
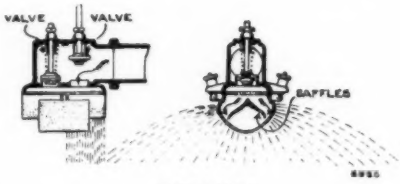


FIG. 2.



FIGS. 4 AND 5.

STREET WATERING CAR.

is worked altogether independently of the pipes under the two platforms. It has been so devised that the intensity of the discharge remains constant, no matter what the level of the water may be in the tank, and consequently irrespective of the head upon the same. In order to effect this the water is forced into the pipes by means of a small electrically driven pump. The latter is located underneath the reservoir and consists of a cylinder which accommodates a rotary pump. Upon the circumference of the rotating part are fitted movable vanes or paddles which by the action of springs are able to be depressed into cavities in the barrel or open out again until they fit close against the interior of the cylinder. The axis of the pump is eccentric to that of the cylinder, so that the paddles open and close more or less as the distance between them and the enclosing wall varies. The water from the tank runs through the intervals between the vanes, and owing to the rotary motion, is forced by the latter under pressure into the sprinkling apparatus or "rose." A regulator placed inside the reservoir and connected by means of a pipe with the escape of the pump, enables the water pressure to be increased or decreased. This regulator is under the direct control of the operator, the regulation being obtained by returning to the tank a portion of the water propelled by the rotary pump. As a certain pressure in the pipes corresponds to a certain distance for the lateral jet, it is very easy to regulate the field of action by means of the regulator. The latter also acts as a safety valve, for when the pressure of the water is too high the water can flow back into the tank. A 4 h p. shunt-wound motor drives the pump through the medium of helicoidal gears enclosed in a casing. The lateral discharge may occur either with or without pressure, according as the small pump is made to work or not. In the first case the reach of the cascade is greater and remains constant. On the other hand when the pump is not acting the water flows away freely, and the length of the jet varies with the height of the contents of the reservoir in the same way that it does with the ordinary water cart. In addition, the "rose" which produces the lateral shower enables the quantity and area of the discharge to be regulated independently of the small pump. In order to effect this the "rose" is made in the form of a perforated cylinder in which a piston (figs. 2 and 3) works. A slide piece of the shape of a segment of a cylinder, fixed to the piston, closes the whole or a portion only of the holes, according to the angular displacement given to the piston (fig. 3), which latter regulates the discharge of water both by its longitudinal displacement and by its rotation on its own axis. In the extreme position (Fig. 8) the piston stops the flow and closes all the holes, and according to the greater or less distance which it is drawn, it opens a corresponding number of the latter, and in this manner enables the output to be regulated. As regards the

amplitude of the curve of the lateral cascade, it can be easily controlled by varying the inclination given to the jets, which is effected by the action of the slide piece mentioned above. It is therefore possible to regulate the distribution of the water on either side of the car, and likewise to water the entire width of the road. The refilling of the tank is effected on sidings established in the vicinity of the standard pipes in the streets. With the aid of a couple of india-rubber hoses of 45 mm. diameter the reservoir can be filled in about ten minutes. The charge of 10 cubic metres is sufficient for watering a distance of 5 kilometres over a width of from 8 to 14 metres. The car travels at an average speed of 12 kilometres per hour. During the summer of the year 1904 the electrical watering car sprinkled on an average from 500,000 to 600,000 square metres per day. The work of an ordinary water cart of a capacity of two cubic metres, drawn by one horse only, amounts to from 100,000 to 120,000 square metres. The working expenses for the car only amount to about £1 per day. This amount includes cost of current as well as the share in the general outlay and salaries paid. Since the output of the electrical watering car is equal to that of five ordinary water carts, for which the working expenses are 10s. 6*d.* each, there is therefore effected a saving, which for an average of say one hundred working days corresponds to an annual economy of nearly £160. In order not to dislocate the ordinary service of the trams, the watering car starts immediately after a passenger car and arranges its course so that it is not overtaken by the one following until it reaches the first refilling station or arrives at the terminus. The water carts drawn by horses have frequently to get out of the way in order to allow the trams to pass, especially in streets where the traffic is great, the consequence is that the operation of watering is not continuous, a drawback that disappears with the use of the car we have been describing. The latter was constructed by the firm of Van der Zypen and Charlier, of Cologne-Deutz. The lateral jets, the pump, and the pipes under the platform were supplied by Helmers, of Hamburg, while the electrical plant was furnished by Siemens-Schuckert. The car was fitted up in the workshops of the municipal trams of Cologne.

A New Torsion Meter.

A new and perfected form of torsion indicator, by means of which the torsion of revolving shafts may be easily ascertained, thus enabling the horse power transmitted to be accurately calculated, has been recently put on the market by Messrs. Kelvin and James White, Ltd., Glasgow.

The instrument which is called the "D. and J. Patent Torsion Meter," is the joint patent of Mr. Archibald Denny, and Mr. Charles Henry Johnson, an electrical engineer with Messrs. William Denny and Brothers.

In Fig. 1 is shown the general arrangement of the apparatus as applied to turbine driven shafting. On the shaft, the torsion of which it is desired to measure, are fixed at a suitable distance apart, two light gunmetal wheels *A*. and *B*. On each of these a permanent magnet is mounted, the projecting pole of which is made **V** shape in order to produce a dense and definite magnetic field at the point. Underneath the magnets and set concentrically with the wheels and shaft are fixed two inductors *A*. and *B*. each of which consist of a quadrant shaped piece of soft iron carried on a gunmetal stand provided with suitable levelling screws. On each piece of iron are mounted a number of separate but similar windings of insulated wire, there being a certain suitable number of windings per unit of circumferential length of the iron. In conjunction with the inductors is a recording box in which are mounted two sets of contact studs, around which are fixed scales. Electrical connection may be made at will between any desired stud of a series and its contact arm. In series *A*. there is a stud for every separate winding in the corresponding inductor, a similar arrangement obtaining in series *B*. and its inductor. Each stud is connected to its particular winding by means of a separate wire, all of which are contained in the multiple cables. The remaining ends or returns of the windings on the inductors are all connected by means of two common wires which are also contained in the cables *A*. and *B*. to the contact arms *A*. and *B*. respectively. Included in each of these two circuits is a variable resistance by means of which the strength of the current flowing in the circuit may be adjusted as desired and one winding of a differentially wound telephone receiver. The scale *A* is divided into five equal parts, there being six separate windings in the inductor *A*. and thus six studs in the series *A*., the length of the scale thus represents the circumferential length occupied by all the windings on the inductor, each sub-division representing the distance between neighbouring windings which is usually 0·2 of an inch. The scale

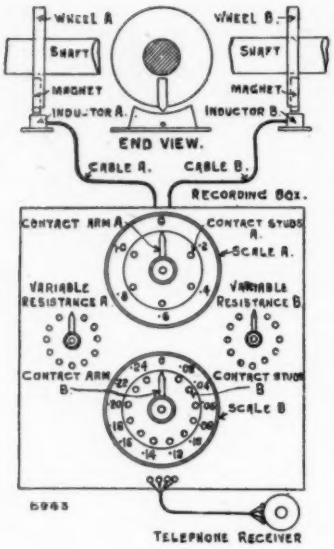


FIG. 1.

FIG. 3

B. is divided into thirteen equal parts, there being fourteen separate windings on the inductor *B.* and thus fourteen studs in the series *B.* The distance between neighbouring windings is represented by one division of the scale; the usual distance between neighbouring windings in inductor *B.* is 0·02 of an inch. The wheel in connection with the inductor at the turbine end of the shaft is set so that the magnet fixed to it is exactly above one or other of the two end windings in the inductor.

The wheel in connection with the other inductor is also set so that its magnet is

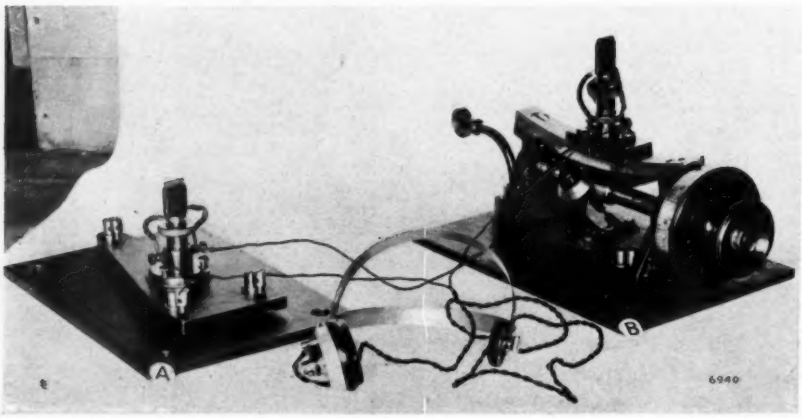


FIG. 2.

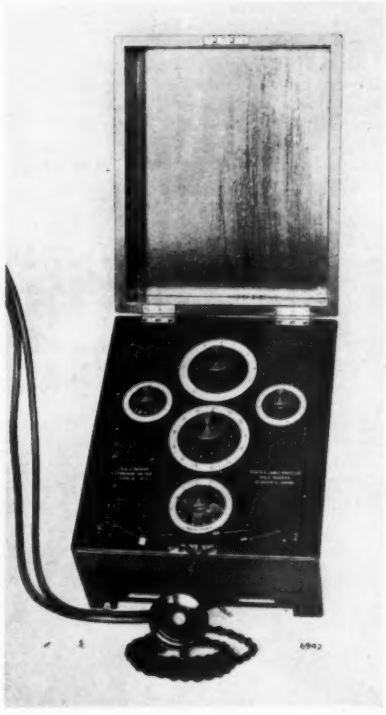


FIG. 4.

exactly above one of the two end windings in the inductor, the correct end winding to set the magnet to in this case being that one from which the magnet will travel in the opposite direction of the other end winding when the shaft rotates. To facilitate the accurate and easy setting of the magnets above their respective windings, lines are cut in the tops of the inductors exactly above the end windings, and the magnets are set to these lines. When the shaft rotates without transmitting power a current of electricity is induced in the end or zero winding of each inductor, the contact arms being first placed in contact with the end or zero stud in each series. These two separate currents each traverse their respective circuits, passing in each case from the inductor winding in which they are induced to the respective zero studs to which these windings are connected, thence by way of the respective contact arms, resistances and telephone receiver windings back to the inductors again. The connections to the receiver windings are so arranged that the effects of the two separate currents flowing therein are in opposition and thus neutralize each other's effect on the receiver when the strengths of the two currents flowing are exactly equal at the same instant. By means of the variable resistances in each of the circuits the currents are made equal in strength and then so long as the shaft transmits no power and is thus subject to no torsion no sound will be heard on listening at the receiver, since the currents induced in the zero windings of the inductors have been equalized and are both induced at exactly the same instant. When transmitting power the shaft is subject to a certain torsion or twist which causes the zero winding of the inductor next the turbine or engine to be excited in advance of the other by the amount of the torsion of the shaft, a loud ticking sound will then be heard in the receiver as the currents no longer neutralize each other.

Contact arm *B.* is then shifted from stud to stud until the position of greatest silence in the receiver is once more obtained. When this position is found, the reading on the scale *B.* opposite the contact arm represents the circumferential measurement of the angle of torsion of the shaft at the radius of the inductor windings. A current equal in strength at the same instant to that induced in the zero winding of inductor *A.* is now being induced in that winding of inductor *B.* which is in connection with the contact arm *B.*, the scale reading thus represents the displacement of one magnet with regard to the other due to the torsion of the shaft. In the event of the torsion being found to be too great to be measured on scale *B.* alone, contact arm *A.* shifted from stud to stud until a reading can be obtained on scale *B.*, the torsion reading being equal to the sum of the readings on scales *A.* and *B.* The reading corresponding to any large displacement of one magnet relatively to the other is thus easily obtained by the combined use of the scales *A.* and *B.*

This instrument was designed and made, because unlike the reciprocating engine it is impossible to obtain the power by means of indicator diagrams in the case of a turbine, and Messrs. William Denny & Bros. foresaw that if success in speed prediction was to be attained in turbines, some means must be deviscd for ascertaining accurately the power developed and transmitted from the turbine.

The instrument has now been tested

exhaustively on no less than ten of the turbine steamers built by that firm, and has proved entirely satisfactory, an average accuracy of 99 per cent. in the readings taken being easily obtained. The recording box is usually placed in a quiet cabin as, while the sound in the telephone is quite definite for fine adjustments, it is desirable to have as little extraneous noise as possible. A further development has recently taken place, not in those instruments, but in additional facilities for recording trial results. A recording machine with a strip of paper is also fitted in this cabin with a pen for recording the revolutions of each engine by means of electric contacts, and a further pen connected from the watch of the observer on the bridge who is taking the time on the mile. There is also a pen marking half-seconds from a standard clock. By means of these the observer in the cabin is advised when the ship is on the mile, and makes his observations of power quite independently of any advice from the engine-room; the revolutions are at the same time recorded. It is thus practicable to report the result of a run in speed and power within a few minutes of being completed.

Fig. 2 shows the two inductors of a rather different form of torsion meter. The inductor *A* consists of a thin soft iron core wound with insulated wire and mounted on a suitable base.

The inductor *B* consists of a similar core and winding on a slider mounted on a quadrant shaped guide in such a manner that by turning a hand wheel the slider carrying the core may be moved backward or forward along the guide. A telephone receiver is arranged in circuit with the inductors as shown, and each inductor is set beneath a wheel (not shown) carrying a magnet as in the case of the previously described instrument. To take a reading, the hand-wheel is moved until silence is obtained in the receiver, the amount of this adjustment is then noted and is the amount of torsion of the shaft. This form of torsion meter is specially suitable for very low rates of revolution and can be easily arranged to measure the torsion of a shaft driven by ordinary reciprocating engines. As the torsion of this class of shafting is variable during a revolution (due to the uneven turning moments of steam engines), six magnets are employed on each wheel instead of one, and these are spaced equidistant about the circumference of the wheels and are arranged each in a different parallel plane. The inductors are as shown, except that there are six separate windings mounted on each inductor base, the six windings on each inductor being arranged in line with the shaft and in the same planes as the magnets carried by the wheels.

A switch is arranged by means of which any desired pair of windings on the two inductors may be connected in circuit with the receiver at a time, and as in the previous case, resistances are provided for adjusting the strength of the induced currents.

By these means the torsion at six different points of the circumference can be easily and rapidly measured consecutively, and from these readings the mean torsion during a revolution is obtained for any constant condition of trial lasting for a short period.

An experiment was made with this instrument in the case of a reciprocating engine, whose turning moment was known to be far from regular, and it was found that with six magnets placed equally round the wheel the greatest possible error did not exceed 4 per cent., and by working out a polar diagram of torque and arranging the magnets suitably round the wheel the error involved did not exceed 1 per cent. It need not be pointed out that for laboratory or factory work in addition to marine work, these instruments should prove extremely valuable.

Figs. 3 and 4 are from photographs of a set of the first-mentioned type of instrument, viz., for turbine work, were taken on a turbine steamer. Fig. 3 shows the disc fixed at one end of the centre shaft. The disc fixed at the other end of this shaft, and to the remaining shafts is exactly similar.

Fig. 4 shows the recording box. The switch marked "inductors" to be seen in the box is for the purpose of connecting the inductors belonging to any one of the three shafts to the recording box so that the readings for all the shafts can be obtained from the same recording box. The studs opposite which the letter *Z* is marked on the scales are for the purpose of testing the accuracy of the Zero of the inductors.

From the foregoing description it will be seen that one of the outstanding features of all the instruments is the total absence of all rubbing contacts. From this consideration, coupled with the fact that they are subject to no wear and tear, and that they generate their own current and require absolutely no attention when not in use, make them very suitable for fixing permanently on board ship, thus allowing of a daily reading of the power being taken, which would permit of anything causing loss of efficiency to be at once detected.

Messrs. William Denny & Bros. inform us that this problem had previously been

attacked by them some ten or fifteen years ago dealing with factory shafting, but without practical success. With the advent of turbines, however, they determined that a proper solution must be found. These instruments are the result, and Messrs. Denny speak highly of the originality and perseverance of Mr. Johnson in carrying this work to a successful conclusion.

Power Gas, with Special Reference to Suction Plant.*

F. H. Bowman, D.Sc., F.R.S.E., M.I.E.E., &c.

The improvements made during the last few years in Internal Combustion Engines have given a great impetus to their use for all purposes, and specially for the generation of electricity for light and power distribution.

From a position of great inferiority to the steam engine they have now become powerful rivals, and both for practical and theoretical reasons they are now looked upon as likely to place in our hands a machine which, while equally reliable in every respect will far exceed the steam engine in economy.

In raising steam we have the combustion of the fuel in the furnace generating heat. A pound of coal when consumed in the most economical manner liberates about 14,500 B.T.U., and this quantity of heat if entirely employed in evaporating water would evaporate about 13 lbs. of water from 62° Fahr., or 15 lbs. of water if supplied at the boiling point 212° Fahr.

This, however, can never be realised in practice, because there so many sources by means of which portions of the heat are lost, and these may be summarised as follows:—

	B.T.U.
1. Loss in heat carried away in the ashes	135
2. Loss in radiation from the surface of the boiler	675
3. Carried away as waste heat up the chimney...	2,970
Total loss	3,780

The coal is never perfectly pure and free from ash, and commercially it would only generate on combustion 13,500 B.T.U. and not as above 14,500 B.T.U.

Compared with the 13,500 B.T.U. per lb. of coal in the furnance this represents a loss of 28 per cent.—before one single pound of steam can be delivered to the engine.

In a producer the loss of heat in changing the solid fuel into gas does not exceed 13 per cent. of the total heat units which would be given out by the complete combustion of the coal. Again, taking the heat units in a pound of coal at 13,500 B.T.U. we have a loss of 1,755 B.T.U.

These causes may be summarised as follows:—

1. Heat carried away in the escaping gases	8 per cent.
2. Heat absorbed by dissociation of the solid fuel and the water vapour in the air	2 ,,
3. Heat lost by radiation ...	1 ,,
4. Undecomposed carbon-dioxide	2 ,,

These figures are only approximate, as they will differ with the form and size of the producer.

The largest portion of the loss is the heat in the gas generated, and which has to be cooled down to the temperature of the air before it can be available for a gas engine. This probably accounts for two-thirds of the total loss. A considerable portion of this heat may be recovered by making the producer regenerative and heating by this waste gas the incoming air required for combustion, and where a suction plant is used by raising the steam necessary to mix with the air, and so keep down the temperature of the combustion, and by the decomposition of the steam in the producer enrich the gas by the liberation of hydrogen and the production of carbon-monoxide without any admixture of nitrogen. By this means from a pound of coal 11,745 B.T.U. can be delivered to the gas engine, as against 9,720 B.T.U. in the steam to a steam engine, and what is equally as important, the cooled gas is far more fixed and stable than the steam, which from its easy condensibility, can rapidly loose a further quantity of its heat units. This gives us the first cause why the use of a gas-driven plant is more economical than a steam plant.

Producers may be considered as comprising two classes:—

I.—Pressure Plant.—Where the air and steam is forced into the producer by means of a blowing engine, a fan or other form of blower or a steam jet.

II.—Suction Plant.—Which can only use non-bituminous fuel, such as anthracite or coke.

* Abstract of Paper read before the Leeds section of the Institution of Electrical Engineers.

Up to the present time 1,000 B.H.P. gas engine seems to be the largest practical and economic unit which can be taken from one cylinder even when double-acting, but multiple cylinder engines are being made from which a larger power may be obtained, and two or even four engines may be coupled so as to obtain a larger unit.

Pressure plant with bituminous fuel may be used for these large units because they will generally be placed where there is sufficient space and where bituminous fuel can be obtained cheap. It will pay also in this case to use recovery plant, and the sale of the residuals will in this country, probably for some time, go a long way in the reduction of the price of the gas and diminish the greater expense arising from the outlay of capital and expense of working. They are not, however, advisable for intermediate sized plant, and ought not to be put down for any size under 1000 B.H.P.

Where units of above 2,000 B.H.P. are required in one machine up to the present time steam is to be preferred to gas, but of course with gas units of 2,000 B.H.P., which represents a 1,200 K.W. dynamo, any sized power station can be constructed and no increase in size would give increased economy.

With a good bituminous plant and recovery of residuals and a modern gas engine developing 1,000 B.H.P. on a full load, a B.H.P. can be produced at a cost of under 0·2 pence per hour, including everything, and a K.W. hour for 0·25 pence per hour at the pole of the dynamo. With a pressure plant such as a Dowson, using anthracite or coke, a B.H.P. may be obtained, including everything for about 0·45 pence per hour and a K.W. hour for 0·6 pence per hour.

The best results known to the author on a 1,000 B.H.P. steam plant give 0.33d. per B.H.P,, including everything. All pressure plant, however, have one disadvantage—they require power to produce the blast necessary to force the air and steam through the system, and they require storage for the gas unless the requirements are perfectly uniform, which is never the case, when the gas is used for power purposes. They require also a separate steam supply, and experiments have proved that when the best results are attained about 16 per cent of the total fuel used is consumed to generate this steam.

In 1888, M. Bénier, a Frenchman, conceived the idea that these disadvantages might be overcome by arranging a closed producer in such a manner that the air might be sucked through the producer by a suitable pump, instead of forced into it by means of the steam jet, and that the gas thus aspirated might be delivered stroke by stroke to the engine as and when generated, and thus do away with the necessity for a gas-holder. Also that the aspiration of the pump would produce a slight vacuum in the producer and scrubber, and thus the waste heat when cooling down the gas could be utilised in an open boiler to generate the steam necessary to be mixed with the incoming air so as to enrich the gas with the necessary hydrogen.

In continuing his experiments, Bénier himself found that a separate pump was unnecessary, as the suction of the piston of the engine in its outward stroke was sufficient to draw the gas through the system.

The correct regulation of the steam to the air supply and the control of the fire while the producer was in operation was not provided for; while the exact proportions between the area of the fire and the heating surface of the boiler and the relations of these to each other and the temperature of the furnace and the relation of the whole to the size and speed of the engine was not understood.

The first suction plant put down in this country to drive a public electric lighting plant was at the Suffolk Electricity Supply Company's station at Stowmarket, and the following analysis of gas was taken from the producer at this station :—

	Per Cent.
Carbonic oxide (CO) ...	21·8
Hydrogen (H)	20·3
Oxygen (O)	0·2
Total combustible gas	42·3
Carbonic dioxide (CO_2). .	7·8
Nitrogen (N)	49·9
	100·0

The one disadvantage of a suction gas producer is that it cannot be worked on an absolutely light load for any length of time, because when no air or an insufficient quantity of air is drawn into the producer the temperature of the fuel falls, and so at last it is reduced to the point that good gas is not produced. This is specially the case in small plants were the volume of incandescent fuel is small. The limit of satisfactory working on light load seems to be about one-fifth of the total load. A 50 B.H.P. engine will not work for long under 10 B.H.P. In large units where there is a greater reserve of heat the elasticity is

greater, and no difficulty is experienced in taking off or putting on a large proportion of the load without any variation in the running.

In making comparison between the advantages of a power plant with suction producers and any other form, such as steam or water power, the limitations already named must be taken into account. For single units above 2,000 B.H.P. no advantage can at present be gained over steam or water power where bituminous fuel is cheap or the water supply abundant, but the advantage is that even with units from 100 B.H.P. up to 500 B.H.P. as great economy can be obtained as with the largest steam or water plant under the most favourable conditions, and thus even small industries can obtain power under the "most favoured nations clause" for commercial competition.

If a comparison is made between a gas engine using town's gas, and the same engine with suction producer gas, the results are very remarkable and differ of course with the cost of the town's gas and the anthracite. A plant recently put down in Yorkshire at the works of the Weldrivet Boiler and Motor Co., Ltd., Halifax, drives a 60 B.H.P. Campbell gas engine, and the power which is on the average about 30 to 40 B.H.P. is distributed electrically. The cost per week of 54 hours with town's gas at 2*s.* 6*d.* per 1,000 cubic feet was about £3 18*s.* 0*d.* per week. Since the suction plant has been put in the cost of the anthracite coal has not exceeded 14*s.* per week, or rather less than one-tenth of a penny per B.H.P. Compared with using town's gas we may say roughly the saving is about

	Saving. Per Cent.
Gas at 1*s.* 4*d.* per 1,000 cubic feet ...	50
,, 1*s.* 9*d.* ,, ,, ...	60
,, 2*s.* 0*d.* ,, ,, ...	66
,, 2*s.* 6*d.* ,, ,, ...	70
,, 3*s.* 0*d.* ,, ,, ...	75
,, 3*s.* 6*d.* ,, ,, ...	80
,, 4*s.* 0*d.* ,, ,, ...	84

The table below gives the results of a trial made on a small plant used at the experimental station of the Dynamic Gas Co. in Manchester.

This test speaks for itself, and it may be interesting to note that since the test was made by the use of a special mixture of fuel the cost of fuel per indicated horse-power was reduced to under one-thirteenth of a penny on a two days' test.

Looking at the inclusive cost of a brake horse-power we may take the value of the plant as follows:—

Producer	£110
Engine	£105
	£215

Cost of running per hour based on 300 days per annum of 10 hours each = 3,000 hours:—

	£
Quarter time of attendant based on wage 25*s.* per week	18
14 tons of coal at 26*s.*	18
Oil, waste, water, &c.	10
Rent, rates, and taxes	10
Depreciation and interest 10% ...	21
	£77

$$\frac{77 \times 20 \times 12}{3{,}000 \times 12} = \frac{18{,}480}{36{,}000} = 0{\cdot}51 \text{ pence per B.H.P. per hour.}$$

TEST OF DYNAMIC GAS PRODUCER OF COAL CONSUMPTION.

Name, Size, and Speed of Engine, and Description of Brake.	Condition of Producer before and after Test.	Starting up Producer. Time.	Coal Consumption. Best Welsh Anthracite Nuts Used.
Crossley Brothers' "Otto." 8½ inch cylinder. 15 ,, stroke. 250 revolutions per minute. Brake, 44 in. diameter to centre of rope. Weight of cast-iron pan ... 101¾ lbs. Weight in pan ... ... 42 143¾ Spring balance showed ... 8 (*W*—*w*) = 135¾ Explosions counted every 30 minutes. Varied from 106 to 110 out of poss. 125. Brake horse-power ... ... 11·5 Indicated ,, ,, ... 12·5	Producer working the day before shut down at 5 p.m. Producer half full of fuel. Ashpit cleaned out before starting test. AFTER TEST. After test contents of ashpit were riddled out through a ¾ inch. mesh riddle. Unconsumed large coal ... ... 13 lbs. Unconsumed small coal ... ... 10 lbs. Ash, 4 % ... 3 lbs. Fuel in producer left at same level as before the test.	Started to blow up Producer with hand fan ... 11-0 a.m. Got gas ... ... 11-5 ,, Engine started ... 11-6 ,, Fan stopped ... 11-6 ,, Load on brake .. 11-7 ,, Engine up to speed 11-11 ,, Put in first charge of fuel ... ... 11-11 ,, Put in last charge 3-35 p.m. Engine shut down 4-10 ,, Total time of test 5 hours.	Total coal put into producer ... ... 74 lbs. Ash, 4 % ... ... 3 lbs. 71 lbs. Unconsu. large coal 13 ,, small coal 10 — 23 Total coal used... .. 48 lbs. $\frac{48}{5}$ = 9·6 lbs. coal per hour $\frac{9{\cdot}6}{11{\cdot}6}$ = 0·835 lbs. per B.H.P. $\frac{9{\cdot}6}{12{\cdot}5}$ = 0·768 lbs. per I.H.P. COST OF RUNNING. Coal 32/- per ton 7th of a penny per B.H.P. hour. 8th ,, ,, I.H.P. ,, This is for fuel only.

From this it will be clearly seen that the use of such a plant as against any small steam engine and boiler of the same size, which would probably be a vertical boiler and engine combined, offers a very great advantage, since any engineer who has had experience of such a plant knows that a continuance of 12 B.H.P. could not, including everything as above, be obtained with such a plant at three times this amount.

Treating such a small plant as the generating station for the electric light it will with 12 B.H.P. supply 120 16-c.p. incandescent lamps, and to get the cost per unit of electricity, there must be added the interest at 10 per cent. on the cost of a suitable dynamo, which, with strap to drive, fixing, and accessories, may be taken to cost £80. The interest at 10 per cent. will be £8 per annum, and we have, therefore, to add to the 0·51 pence per B.H.P.

$$\frac{8 \times 20 \times 12}{3{,}000 \times 12} = \frac{1{,}920}{36{,}000} = 0{\cdot}053 \text{ pence,}$$

which brings the cost up to 0·563 pence. Adding one-quarter to this we get the cost per B.T.U. per hour — 0·704 pence per hour, which is a little less than ¾*d.* per B.T.U.

The following is the cost given to me of a similar sized steam plant :—

Coal per unit	0·572	pence.
Attendance	0·395	,,
Oil	0·056	,,
Water	0·050	,,
Waste, cleaning, &c.	0·032	,,
Interest and depreciation on £280	0·210	,,
Cost per unit per hour ...	1·415	pence.

It is clear, therefore, that for an installation this size there is a very decided saving, viz., about 0·7 pence per unit, which shows that the gas plant produces the unit at half the cost of the steam plant at the pole of the dynamo.

The steam plant was a self-contained upright engine and boiler, working at 120 lbs., and driving by a belt on to the dynamo. The capital outlay on the steam plant was £280, and the gas plant £295, or £15 dearer than the steam plant, but it is twice as efficient.

Taking the annual working expenses of a 500 I.H.P. steam and gas plant for the same output, we have £1,880 — £1,575, equal to a saving of £305, which is equal to a profit of above 5 per cent. on the capital outlay of the gas plant. The same relative proportions will be found to hold good up to 1,000 I.H.P., but as already stated the present mechanical status of the gas engine prevents economical units beyond, say, 2,000 B.H.P. and steam then holds its own.

With continuous running of course better results can be obtained, even with smaller gas plant, and the following may be taken as an example, being run continuously for weeks together at the works of the British Westinghouse Company, Limited, Trafford Park, Manchester.

Cost of Gas Plant, &c.

130 B.H.P. Dynamic Gas Producer...	£250
Cost of Vertical 3 Cylinder Gas Engine, and 75 K.W. direct coupled Dynamo, with switch board ...	1,600
	£1,850

Cost of Running, say, 8,700 Hours per Annum on 80% Load.

	£
Three men, 28*s.* each per week, three shifts of eight hours...	219
Oil, waste, cleaning, &c.	80
Water	100
Coal, 320 tons at 26*s.* (Anthracite nuts)	416
Sundries	50
	£1,050

$$\frac{1{,}050 \times 20 \times 12}{8{,}700 \times 80} = \frac{252}{696} = 0{\cdot}36 \text{ per B.H.P.}$$

0·45 per K.W. hour.

If there had been a free water supply... ...	0·41	,, ,,
If on full load	0·31	,, ,,

The continuous improvements which are being made in gas engines, however, seem to indicate that before long still larger units may be advantageously employed, and while the efficiency of the gas engine is considerably higher than that of the steam engine at present, the possibilities of future improvement are much greater.

RAILWAYS.

High Speed Electric Locomotive.

The accompanying illustration is that of the first electric locomotive designed and built for the New York Central and Hudson River Railroad by the General Electric Company and American Locomotive Company. It possesses several features of interest, in particular, the motors are gearless, without spring suspended quills; the shape of the pole-pieces and the diver-

sion of the magnetic flux. A previous example of gearless motors without quills is to be found in the locomotives employed on the Central London Railway, which were however abandoned in favour of the motor car system. In these locomotives however, the axle supported the entire motor instead of only the armature, as is the case in the locomotive under consideration. The latter method involves a total dead weight on each axle, including two 44in. wheels of only 11,000 lbs., which, considering the absence of reciprocating parts, should reduce the wear on the rails that arises in the case of the steam locomotive from the impossibility of perfect balancing connecting rods, etc.

According to the *Street Railway Journal** it is thought that the reduction in upkeep of the permanent way due to the absence of pounding and also from the intermittent torque, will be considerable, being estimated at from 20—30 per cent.

The mounting of the armature directly on the driving axle called for an arrangement of pole pieces such that the armature should be free to move up and down between them with the riding of the frame on the springs. The pole-pieces have, therefore, been made with nearly flat faces, their spacing from the armature leaving an air gap of ¾-inch.

The magnetic flux is continuous from one end of the truck to the other; that is, the fields are arranged in tandem, and the flux passes through all poles and armatures in series, returning partly by the cast-steel side frames and partly by two bars placed between the frames, but not over the iron core of the armature. In order to take care of any inequalities of air gap and wheel diameters of the several elements, cross transoms are provided, which connect the side frames and act as equalisers for the individual motors. This makes each motor practically independent of the others, although in circuit with the main flux. The end pole-pieces are cast as part of the end frames, while the double pole-pieces between the armatures are carried by the steel transoms already mentioned. The field coils are wound upon metal spools which are bolted upon the pole-pieces.

The designers have been very successful in regard to commutation, a current of 1,000 ampères at 650 volts in no way indicating its presence at the brushes.

The brush holders are mounted on insulated supports attached to the spring saddle over the axle journal, thus maintaining a fixed position of the brush holder in relation to the commutator. These brush holders are made adjustable so as to allow for wear of the commutator and journal bearings.

The motor is protected from mechanical injury from below by brass screens which extend from pole piece to pole piece, but which are not carried up at the side of the motor. This provides most effective ventilation, and at the same time all the mechanical protection which it is thought is required. Both the main frame and superstructure is suspended from a system of half elliptic springs and equalising levers. The pony trucks are of the radial type and are pivoted by means of radius bars to the end frame of the main truck. The superstructure consists of a central cab for the driver containing the usual apparatus which, however, has been arranged in duplicate. A corridor extending through the cabs gives access to the cars behind.

The total weight of the locomotive is 95 tons, of which 69 tons are carried on the four pairs of drivers. This is a very much larger percentage than in the steam locomotives of the company, the heaviest of which weigh, including tender, 150 tons, of which 47 tons are on the two pairs of drivers. In other words, there is over 25 per cent. greater weight available for traction than on the largest locomotives in the New York Central service, with 37 per cent. less dead weight and with 28 per cent. less weight on each axle.

The locomotive possesses four driving axles, on each of which is mounted, without intermediate gearing, the armature of an electric motor having a normal rating of 550 h.p. The total rated capacity of the locomotive is 2,200 h p., although for short periods, a considerably greater power may be developed, making it more powerful than the largest steam locomotive in existence. It is equipped with the Sprague-General Electric multiple-unit system of control, so that if desired, two or more locomotives can be coupled together and operated from the leading cab as a single unit. A single electric locomotive will be able to maintain the schedule of from 60 to 65 m.p.h. with a 450-ton train, and two locomotives will be coupled together for heavier trains, some of which in the New York Central service reach 875 tons in weight.

On tests made with an eight-car train weighing including the locomotive 431 tons and a four-car train weighing 265 tons, a maximum speed of 63 m.p.h. and 72 m.p.h. respectively was reached.

A speed of 30 m.p.h. was reached in sixty

* Vol. XXIV. No. 21.

NEW YORK CENTRAL ELECTRIC LOCOMOTIVE.

seconds with the eight-car train, corresponding to an acceleration of ½ m.p.h. per second. During certain periods of the acceleration, the increase in speed amounted to ·6 m.p.h. per second, calling for a tractive effort of approximately 27,000 lbs. developed at the rim of the locomotive drivers. This value was somewhat exceeded with the four-car train, where a momentary input of 4,200 amps. developed a tractive effort of 31,000 lbs. at the drivers, with a coefficient of traction of 22·5 per cent. of weight on drivers. The average rate of acceleration with the four-car train weighing, including the locomotive, 265 tons, was thirty miles in thirty-seven and one-half seconds, or ·8 m.p.h. per second, calling for an average tractive effort of 22,000 lbs.

The maximum input recorded, 4.200 amps. at 460 volts, or 1935 k.w.. gives an output of the motors of 2,200 h.p. available at the wheel. With 4,200 amps. and a maintained potential of 600 volts, there would have been an input to the locomotive of 2,520 k.w. corresponding to 2,870 h.p. output of the motors. This output is secured without in any way exceeding the safe commutation limit of the motors and with a coefficient of traction of only 22.5 per cent. of the weight upon the drivers, thus placing this electric locomotive in advance of any steam locomotive yet built.

Bridging the Zambesi.

ANOTHER link in the Cape to Cairo Railway is now being made by the construction of the railway bridge across the Zambesi River, just below the Victoria Falls. The Victoria Falls are 420 ft. high, and 1900 yds. wide, or two and a half times the height and twice the width of the Falls of Niagara. The Cape to Cairo Railway, which has recently been completed from Cape Town to the Zambesi (1,635 miles), and is now being carried on towards Tanganyika, traverses the peninsula of rock immediately in front of the Falls, and will cross the gorge by the bridge just below the "Boiling Pot," as the narrow outlet is called through which the whole river rushes after its tremendous fall. The clear span of the arch, which has just been completed, is 500 ft., and owing to its height above the river—400 ft.—no staging or scaffolding has been employed in its erecton. It has, therefore, been built out from each bank of the ravine, on the cantilever principle, until the steelwork of the arch met in the centre. The bridge, which is sufficiently wide for a double line of railway, has been built by Sir Douglas Fox & Partners, the engineers of the Rhodesia Railways Co. In order to carry across the gorge the materials for the northern half of the bridge and the rails for the extension northward, an electric cable-way of a novel type has been employed. One end of the cable is attached to a rigid tower, and the other end to an inclined hinged support, which is loaded with a heavy weight to counteract the sagging of the cable as the conveyer travels along it. The carrier is suspended from two travelling wheels running on the rope, and consists of a frame carrying a chair for the driver, and the electric motor which propels the apparatus. The conveyer is capable of carrying a load of 10 tons, and can transport 800 tons of material across the river in one day, the amount of railway construction plant which will have to be carried over the river before the work is finished being estimated at 40,000 tons. An interesting picture of the work in progress and a map of the district is given in the *Graphic* of April 1, from which journal the above particulars of the scheme have also been taken.

ELECTRICAL NOTES.

By Andrew Stewart, A.M.I.E.E.

Electrically Driven Lathes at the Washington Navy Yard Gun Factory.*

There are eight large lathes, seven capable of turning 14-in., and one 16-in., guns. Until three months ago these were driven by two 250 h.-p. high-speed steam engines with rope transmission. In order to adapt the lathes to electric driving, the cones on the lathe headstock were turned down to a uniform diameter of $5\frac{3}{8}$ in., and the motor armatures, which had no shaft, were mounted direct on these. The motors are simple shunt wound machines, with six poles, and give 56 h.-p. maximum. In addition there is a 10 h.-p. compound wound motor mounted on a bracket attached to the bed of the lathe; this motor runs the tool carriage up and down the bed. This arrangement appears to save time when handling the heavy tool carriages, as they can be moved very quickly up and down.

* *Electrical World and Engineer*, March 4th.

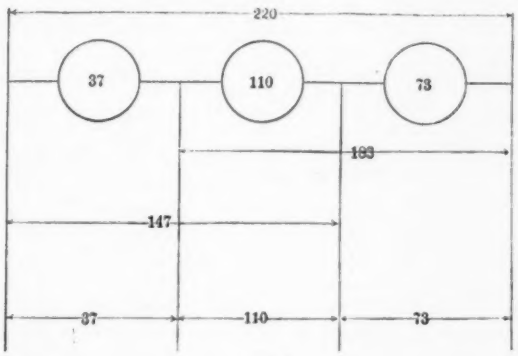


FIG. 1.

The main motors are supplied from a four-wire system, giving six different voltages (Fig. 1); the controller enables the motor to be switched on to either of the following pressures, 37, 73, 110, 147, 183, and 220 volts. In addition to the speeds corresponding to these voltages, there is a back gear, having a ratio of 2·8 to 1, operated by a double-jaw clutch. The range of the motor speed is from 444 to 183 revolutions per minute in twelve steps, at any of which the motor gives 30 h.-p. Lower speeds can be obtained, but the power is correspondingly diminished, though low speeds at full power may be obtained by using the back gear. Taking advantage of every speed, and the back gear, a total range of speed of 25 to 1 may be obtained. The system is balanced by three balancers placed across the 220 volt mains, each giving the voltage indicated (Fig. 1), and the four wires are carried to all the machines. The controller is a standard drum type Crocker Wheeler controller, mounted near the tool carriage. Push buttons are placed round the lathes at convenient points, to enable the operator to stop quickly, without the necessity of going to the controller. The installation, which has saved the labour of six enginemen and greasers, effects a saving of over £2,000 per annum; the engine driving the generators in the central station takes $13\frac{1}{2}$ lbs. of steam per i.-h.-p., against more than twice as much for the old engine plant.

Efficiency of Artificial Lighting.*

In a lengthy paper read to the Cologne Electrical Society, the following interesting data regarding various artificial illuminants

* Paper on "Progress in Lighting Industry," by Herr Wedding, read to Cologne Electrical Society.

	Efficiency.	Calories per candle per hour.	Cost per 1,000 candle-hours in pence.
Kerosene lamp	0·000 29	36·4	10·5
Gasoline	0·000 063	16·3	11
Welsbach incandescent gas light	0·000 18	11·0	3·4
High-pressure incandescent gas light	0·000 65 to 0·000 96	6·48 to 7·82	2·25 to 2·4
"Lucas light"		5·77	1·75
"Millennium light"	0·002 to 0·0048	2.6 to 3.99	15 to 23
Carbon filament electric lamp	0·006 2	1·34	8
Osmium lamp	0·008 5	1·63	9·5
Nernst lamp	0·002 98 to 0·003 38	0·95 to 0·2	5·5 to 1·15
Electric arc lamp			
Flame arc			

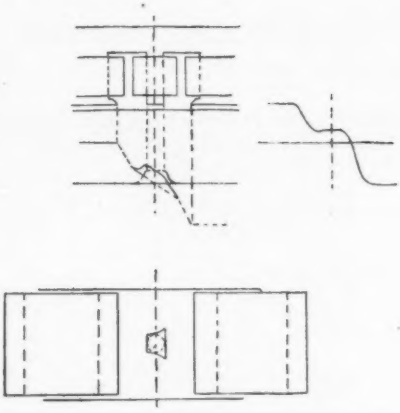
is given. This table is specially interesting as one has an opportunity of comparing the latest development in electric arc lighting, viz., the flame arc lamp, with the Osmium and Nernst lamps, as well as their older rivals. It will be seen that high-pressure gas and oil lamps have but one rival, the flame arc lamp, so far as cost for a given amount of illumination is concerned.

Murnau Ober-Ammergau Single-Phase Railway.*

A SMALL section of the Bavarian State Railways (about 14 miles) is equipped on the Siemens-Schuckert patent single-phase system. Unlike the American line described last month,† the generating station is, in this case, equipped with single-phase generators, though three-phase machines are also installed to supply electrical energy to neighbouring villages. The generators are driven by water turbines, and generate at 5,000 volts and a periodicity of 16⅔ cycles per second. There is no transformation between the generator and the train, but each motor coach carries a single transformer, which transforms the trolley wire pressure of 5,000 volts down to 260 volts, the secondary of the transformer having tappings which are connected to the controller, giving lower voltages at starting. There are, therefore, no rheostatic losses. Each car has two 10-pole single-phase commutator type motors, with special windings to keep down sparking at the commutator. This has hitherto been a source of trouble with some types; these motors are geared to 31½-in. wheels through a spur gear having a ratio of 5·2 to 1. A speed of 25 miles per hour is maintained with or without trailers. The traffic is not often sufficiently great to justify the use of the latter. The motor cars have second and third-class, post, and baggage compartments; they weigh twenty-six tons. On a grade of 1 in 25 they start easily with a gross load of 50 tons. The Siemens-Schuckert Company are said to be constructing a single-phase electric locomotive capable of working with 20,000 volts direct from the trolley wire.

Phoenix - Pohl Dynamos and Motors.‡

THE limiting factors of output in direct current electrical machinery are sparking and



heating, the former frequently exercises a predominating influence on the design. In recent years the demand for motors capable of wide speed control by shunt regulation only, has introduced new problems in the design of such machines, as the reduction of the magnetic induction causes the neutral zone of commutation to change. The Phœnix Dynamo Manufacturing Company have introduced dynamos and motors having auxiliary poles placed midway between the field magnet poles, as shown by the accompanying sketch. These are small, as will be seen from the lower figure, and their effect is to maintain the field necessary for commutation, uniform over a considerable part of the interpolar space. The upper left-hand diagram shows the effect on the flux of rectangular auxiliary pole pieces, while the right-hand diagram shows the effect of the specially shaped auxiliary poles. The magnetic flux is, as will be seen, uniform for a considerable distance. A machine with these poles was overloaded to the extent of three times its normal load without sparking, though without these poles the same machine sparked at normal load. Another machine, with speed regulation on shunt only, was tried at all speeds from 350 to 900 revolutions with equally satisfactory results. The company claim to build motors on this system for (*a*) constant speed between no load and full load; (*b*) speed decreasing with increasing load in order to obtain large torque at slower speeds, and (*c*) for increasing speed with increasing load. (*B* is a requirement often found necessary with some classes of machine tools, but hitherto not generally considered possible.) A method of ventilating the field coils is also described, though ventilated field coils have

* *Electrical Review*, London, March 17th.
† *The Engineering Review*, p. 735.
‡ *Electrical Review*, London, March 24th.

been used by one or two Continental firms for some years. They are apparently considered novel in England; such ventilation keeps the field temperature very low, assuming the same current and weight of copper. The object of most European manufacturers has, however, been to keep down the cost by reducing the field copper and using higher current densities.

Capital Cost and Energy Consumption on Electric Railways.*

SEVERAL articles dealing with European lines having both single and polyphase equipments. The Burgdorf-Thun railway (Switzerland) using three-phase currents and two trolley wires cost as follows:—

	£
High tension feeder (overhead)	5,600
Transformer sub-stations	6,500
Trolley wire and rail returns	14,000
Railway station lighting	800
Rolling stock and electric equipment ...	9,400
Spare gear	1,200
	£37,500

The line is 24 miles long. Another three-phase line in Northern Italy, the Valtellina, is 63½ miles long and cost £200,000. The voltage between the two trolley wires and the rails is 3,000. The energy consumed by a single motor car weighing 54 tons is 58.4 watt hours per ton mile. With four or five trailers aggregating 65 tons, this falls to 45 watt hours per ton mile due to there being no increase in the air resistance on the front of the train. These figures also include starting up and accelerating out of stations. Taking tests with the train at a constant speed of 36 miles per hour, level road, the watt hours for the motor car only are 25.2 per ton mile, and for a train of 120—130 tons 18.2 to 19.7 watt hours per ton mile. The energy wasted in the rheostats, etc., at starting (average of seven starts on a 24 mile run) was found to be 8.7 watt hours per ton mile. Hence, these losses are smaller than is generally supposed. These three-phase locomotives and motor cars are arranged so that they return energy to the line when descending steep inclines. A 110 ton train descending a ·417 per cent. gradient returned nothing to the line, but on one part of the line with very steep gradients 54 per cent. of the potential energy of the train was returned to the line and thus available for assisting trains which were ascending gradients. The results go to show that under these conditions the three-phase system is superior in efficiency to direct current. Some new locomotives are under construction for this line; they have six wheels coupled, and two leading and two trailing wheels; the total weight is 62 tons, of which 42 are on the driving wheels; the normal horse power is 900, which can be obtained, by changing the number of stator poles on the motor, at either 41 or 20½ miles per hour. The normal draw bar pull is 7,600 and 13,200 pounds at the speeds mentioned, with a maximum of 15,300 and 20,000 pounds. The single-phase line in the Stubai Valley in the Austrian Tyrol is also referred to. This line differs from most other single-phase lines in that it is operated at the high periodicity of 42 cycles, which cheapens the cost of generators, motors, and transformers. Each motor car has four 40 h.-p. motors, the connections being similar to that shown in our last issue* for the Indianapolis line, except that the auto-transformer is replaced by a true transformer. The power consumed, including trolley wire and secondary network losses, is 102 watt hours per ton mile, but based on the measurements of train resistance the consumption is only 70 watt hours per ton mile, giving an efficiency from feeding point to rails of 68 per cent.

Elektrotechnik Zeitschrift, February 2nd and 16th.

Power Consumption Manchester Tramways.†

A LENGTHY paper dealing with the supply and distribution of power to Manchester tramways. There are about 144 miles of single track and 400 cars serving an area of 41 square miles; the bulk of the sub-stations supply both traction and light, hence motor generators are employed to convert the high tension three-phase current to direct; the average efficiency of these motor generators taken over a month, has been found to be 78½ per cent. The output per car at the low tension side of the sub-stations comes out at 8½ kilowatts. Figures are given for two types of car, viz., double deck double truck and single deck double truck, showing that with the same average number of passengers on the journey (20) the watt hours per car mile for the former was 1,710, and for the latter 890 watts, though this single deck car made an average of 8 miles per hour against 7·4 for the double deck car. The watt hours per ton mile for the double deck car were 144, and for the single deck car 95, measured on the car. (The difference between the watts per ton mile on the tramway and on the

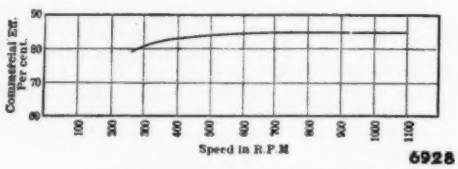
* *The Engineering Review*, p. 735.

† Paper by Messrs. Pearce and Gunton, Manchester Section Inst. E.E.

railways, detailed in preceding abstract, are interesting.—Ed. E.R.) The efficiency of transmission, *i e.*, high tension transmission from generating station to sub-stations is given as 93½ per cent. The load factors at the generating stations differ considerably. At Stuart Street it is 47·8 per cent. and at Bloom Street 29.3 per cent.; the lowest cost per unit at the former was ·27*d.*, of which ·17*d.* was coal, and at the latter ·28*d.* and ·161*d.* respectively. The economy of condensing is clear from the fact that the Stuart Street Station costs rose to ·38*d.* total and ·26*d.* for coal when operating non-condensing.

Electrically Driven Engineering Works.*

THE works of the Electro Dynamic Coy., Bayonne, N.J., are being re-arranged; the smaller tools are grouped in the side aisles, and driven by short lengths of motor driven shafting. Large tools have individual drives; the large drills and lathes have been adapted by simply belting the variable speed motors to the cone, though in one or two cases a special pulley has been substituted for the cone; in other cases the motors have been geared, or driven by chains. In the case of slotting machines, where a high speed motor has to be adapted to a very slow speed tool, the first speed reduction, about 10-1, is by a Renold's chain, and the second, about 15-1, by spur gear, the spur wheel being a solid disc. The chief feature is the use of the variable speed motors, which have auxiliary poles, similar to those illustrated under the description of Phœnix Pohl Motors; these motors drive lathes, boring mills, &c., and are designed to give a speed regulation of 3 to 400 per cent. with scarcely any loss in efficiency (see Fig.), and without sparking. The motors are fitted with ball bearings.



EFFICIENCY OF 5-HP MOTOR AT FULL LOAD.
ELECTRICALLY-DRIVEN ENGINEERING WORKS.

* *Electrical World and Engineer*, New York, March 18th, 1905.

By PERCY LONGMUIR,

Carnegie Research Medallist.

Steel: its Treatment and Properties.

Tungsten and Molybdenum in Steel. In a paper read before the Students' Engineering and Metallurgical Society of University College, Sheffield, Mr. T. Swinden admirably summarises the influence of tungsten and molybdenum on the properties of iron and steel. For this purpose the literature relating to these two elements has been thoroughly studied, and the researches of Professor Arnold, Messrs. Hadfield, Guillet, and others, drawn upon for comparisons. The early recognition of the similarity in effect of molybdenum and tungsten is indicated by a quotation from Percy who, in 1864, stated that "according to Berthier, alloys of tungsten are perfectly analogous to those of molybdenum with iron." Notwithstanding this early recognition, the relative effect of these two elements has formed the subject of many erratic statements, the majority of which, however, agree as to the greater activity of molybdenum. Taking the published data on tungsten first, the author gives a *résumé* of the history of the metal, the method of reduction from wolfram and its uses in steel manufacture. The influence of tungsten on the mechanical properties of pure iron is comparatively slight. As far as tensile tests are concerned, ascending tungsten contents do not give the extraordinary alloys met with in similar series of manganese or nickel iron alloys. Nevertheless, in the presence of carbon, a range of maximum brittleness apparently occurs at from 10 to 15 per cent. tungsten. The widest application of tungsten lies in the production of tool steels where in association with chromium it yields the familiar product known as high-speed steel. The occurrence, history and preparation of molybdenum are similarly treated. The properties of molybdenum steels are not so fully dealt with owing to the absence of published data, which may be probably due to the difficulties met with in producing these steels. Thus Blair, in 1894, quotes a case in which 1 per cent. molybdenum rendered a good iron red, short, and worthless. In 1902, Matthews produced three steels containing 0·95, 1·87, and 3·0 per cent. respectively of molybdenum, the last two breaking under a few blows of a hammer. Guillet, however, finds that in a 0·2 per cent. carbon series alloys up to 10 per cent., and with a series containing 0·8 per cent. carbon steels up to 5 per cent. molybdenum forged readily, but these contents represent the forging limit.* Summarising the influence on mechanical properties, molybdenum behaves similarly, but has a stronger action than that of tungsten. Considering this analogy, there is reason to suppose that a point or range of maximum brittleness would occur if a sufficiently wide series were examined. Turning to the relative effect of tungsten and molybdenum the earlier discrepencies represent insufficient knowledge. Apparently Guillet is the only investigator who has published comparative results obtained from two series of tungsten and molybdenum alloys. As far as comparison permits, 1 per cent. molybdenum gives similar tensile values and structures to those obtained from a 4 to 4½ per cent. tungsten alloy.

Aluminium Steels. Aluminium in traces is extensively used for the production of sound steel ingots, and from this point of view is extremely successful. It has, however, been argued that the small amount present, which seldom exceeds 0·04 per cent., has some effect on the properties of the steel. We therefore turn with interest to a research on aluminium steels by M. Guillet contained in the last issue of the *Revue de Metallurgie* which, whilst it may not directly answer the question as to the influence of traces, certainly gives data as to the influence of an ascending content of aluminium on two types of steel. The two types referred to represent mild and medium hard steel, containing about 0·15 per cent. and 0·75 per cent. carbon respectively. The carbon contents of the latter series are, however, somewhat erratic. The metallography of the two series is fully treated, and trends to show that aluminium enters into solution with iron. This solution retards the development of laminated pearlite and this constituent therefore takes a more or less granular form. Graphite has not been detected, but when the carbon and aluminium are suffi-

* "Molybdenum Steels," p. 232, September issue, 1904.

ciently high a constituent resembling cementite is noted, Subsequent quenching experiments confirm this constituent to be cementite. Turning to the mechanical properties, results obtained from the first series are as follows, the steels being in the normal condition, *i.e.*, reheated to 900° and slowly cooled.

SERIES I.

Content of.		Mechanical Properties.					
Carbon.	Aluminium.	Elastic Limit Kilos per sq. m.m.	Max Stress Kilos per sq. m.m.	Elongation per cent	Contraction of Area per cent.	Frémont Drop Test Kilogram-metres.	Hardness Brinell.
0·085	0·50	26·7	37·1	35·0	68·0	29	81
0·113	1·08	33·6	40·8	30·0	65·2	26	105
0·168	2·04	27·9	44·5	28·0	66·7	2	118
0·134	3·05	27·4	41·4	23·5	32·9	2	131
0·168	5·07	34·4	50·7	21·0	45·9	0	143
0·083	7·18	40·9	46·1	2.0	0	0	159

The tensile results show that aluminium has comparatively little influence on the properties up to 3 per cent., however at this content a diminution of elongation and contraction of area is shown. Shock tests show that aluminium when present in low quantities does not sensibly diminish the resistance to shock. When, however, a content of 2 per cent. is reached the fragility is extremely high. Structurally this point corresponds to the appearance of compact pearlite noted in the micrographic section. Hardness, low at the beginning of the series steadily increases with ascending aluminium, from which it is inferred that the solution of aluminium and iron hardens the alloy. The mechanical properties of the second series are embodied in the following table.

hardness tests show all the steels to be relatively fragile and of a hardness only slightly increased by successive increments of aluminium. The influence of annealing and quenching has been studied on both series. Steels of the first series annealed at a temperature of 1200° C. for 4 hours did not develop laminatad pearlite, this constituent still maintaining its granular aspect. Similar conditions hold for steels of the second series, and it is further noted that in no case was a precipitation of graphite obtained. Quenching experiments lead to the conclusion that the solution of aluminium in iron is incapable of dissolving carbon. Mechanical tests of the steels quenched from 850° C. in water permit of the low carbon series being divided into two classes: (1) When the content of aluminium is below 3 per cent., breaking load and elastic limit are raised whilst elongations and reductions of area are diminished, this diminution being more marked than in ordinary steels of the same carbon content. (2) Exceeding 3 per cent. aluminium the influence of quenching is nil on the breaking load and

SERIES II.

Content of.		Mechanical Properties.					
Carbon.	Aluminium.	Elastic Limit Kilos per sq. m.m.	Max. Stress Kilos per sq. m.m.	Elongation per cent.	Contraction of Area per cent.	Frémont Drop Test Kilogram-metres.	Hardness Brinell.
0·736	0·45	45·8	83·3	5	17·3	2	228
0·669	1·05	46·6	88·8	9	20·5	2	212
0·691	2·89	43·6	73·8	4	4·3	0	228
0·815	4·65	46·7	88·8	11	15·4	0	277
0·663	7·00	68·4	89·4	0	0	2	217
0·860	14·90	66·2	101·9	3	4·2	2	277

The tensile tests of this series show the influence of aluminium as somewhat similar to that noted in the earlier series. It is, however, difficult to deduce the effect of aluminium on maximum stress owing to the variations in carbon, but apparently it tends to increase the breaking load and at a content of 7 per cent. to lower decisively the elongation. Shock and elastic limit, the product giving no elongation or reduction of area. Only a few of the members of the second series have been tested in the quenched state. These tests show that quenching sensibly increases the breaking load and elastic limit. Cementation experiments show that aluminium considerably retards the penetration of carbon. Thus two steels of the

first series, held for 8 hours at a temperature of 1060° C. in a cementing mixture of 40 per cent. carbonate of barium and 60 per cent. charcoal gave the following results.

Aluminium per cent.	Penetration in tenths of 1 millimetre.
1	4
3	2

Under the same conditions an ordinary steel would have shown a carbon penetration of $\frac{9}{10}$ millimetre. At a content of 7 per cent. aluminium cementation ceases.

Foundry Practice.

*Foundry Blackings.** These facings are generally supposed to contain at any rate some plumbago, but probably quite three-fourths of the blacking used in the United States is made from pulverised hard coal. Whilst this coal is generally regarded as being uniform in composition there is none the less a marked difference in the various hard coal blackings as the two following analyses show.

	Good Blacking. per cent.	Poor Blacking. per cent.
Ash	10	18
Carbon	83	73

The poor blacking did not "peel" the castings whilst the one containing low ash and high carbon successfully prevented the sand from adhering. A type of plumbago blacking termed pure plumbago contained ash 47 per cent., volatile matter 7 per cent., carbon 47 per cent., which shows it to be far from pure. In fact there is very little pure plumbago sold for foundry use, the majority of it being adulterated often with soap stone.

Casting Round Flasks in Cores. Moulding by means of cores has, when only a few castings are required, many advantages, chief of them being found in the low initial pattern cost. A method of making circular moulding boxes by this plan is described by Mr. H. J. M'Caslin in the March issue of *The Foundry*. Fig. 1 shows plan and cross section of a portion of the required flask. It will be noted that there are two lines of cored bolt holes round the box and a sand strip on the inside of the top and bottom. Generally four trunnions are cast on each box, one of which is shown in Fig. 1. In making up the mould a level bed is struck off and an offset A. Fig. 2 rammed up to assist in setting the cores. The circle so formed is divided by four equidistant lines to which the centres of the four cores containing the trunnions are set. After the remaining cores are set, sand is firmly rammed inside and out and the mould is ready for casting. Fig. 2 shows a section of the completed mould and method of casting.

* N.W. Shed, The Foundry, March, 1905.

Defects in Ingot Iron Castings.—In the March issue of the *Iron and Steel Magazine*, Professor K. H. Wedding discusses various defects common to ingot iron or mild steel castings. Turning first to blowholes, the absorption of gases by molten iron is indicated. Whilst the metal is fluid these gases frequently form an alloy, but on solidification they may (1) remain alloyed with the iron; (2) be retained between the crystals; (3) escape if an opportunity is afforded; or (4) remain imprisoned in the solidifying iron forming small cavities or blowholes. These blowholes are generally pear-shaped, rarely cylindrical or spherical. Their position will depend upon the rapidity of solidification which in turn will depend, apart from the heat conductivity of the mould, on the temperature of the iron when poured. In "hot" poured iron, the blowholes show on or near the surface, whilst in "cold" poured iron they appear wholly in the interior.

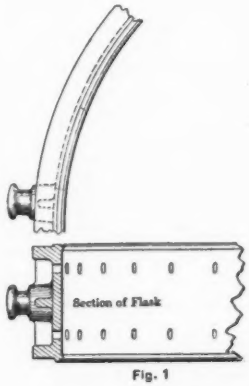
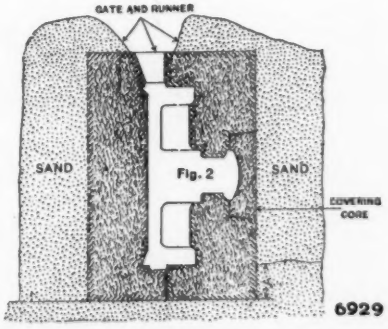


Fig. 1



CASTING ROUND FLASKS IN CORES.

Blowholes may be avoided by correct handling of the molten metal, by slow cooling and by the suitable addition of silicon or aluminium. Of the former element from 0·1 to 0·3 per cent. may be safely added, whilst the amount of the latter should be between 0·03 and 0·05 per cent. One difficulty in properly regulating the casting temperature lies in a lack of measuring instruments for the purpose. The author's efforts to invent a suitable instrument have not yet met with success, but he hopes eventually to find a satisfactory device.

Shrinkage Cavities are a result of the contraction of the iron on cooling and are totally distinct from gas cavities. In order to lessen or avoid them, the most certain method lies in the application of feeding heads on that part of the casting where the shrinkage cavity would appear, *i.e.*, the portion where the metal remains longest fluid. Apart from the form of the mould shrinkage cavities also depend on the casting temperature of the metal, for the hotter the metal when poured, the larger these cavities. But even a relatively cold metal will give rise especially in thin walled castings to the formation of cavities in the interior because by the quick solidification of the crust the pressure of the fluid metal is prevented. After noting gas cavities from sources other than the gases of the metal, *i.e.*, trapped air and mould gases, the author passes to a consideration of hot and cold cracks. The former occur in the casting before stripping whilst the latter develop after the casting leaves its mould. However, the sources of both hot and cold cracks merge one into the other. Hot cracks are produced by the resistance of the mould to the contraction of the casting and their production is also favoured by

I. On Bars Rolled, Drawn, Annealed.

Composition.			Mechanical Properties.					
Copper.	Manganese.	Zinc.	Max. Stress Kilos. per sq. m.m.	Elastic Limit Kilos. per sq. m.m.	Elongation per cent. on 2 in.	Reduction of Area per cent.	Frémont Drop Test, Kilogrammetres.	Hardness Brinell.
57·5	2·60	39·7	35·3	14·2	42·5	73·1	14	57
57·4	3·04	39·5	37·2	14·5	39	51·9	14	57
54·6	4·38	39·6	48·1	16·7	30·5	36·8	13	64
54·8	6·00	40·0	49·2	18·8	29	34·4	12	64
54·3	5·57	39·5	47·4	17·3	31	35·5	12	72
52·3	6·98	39·9	49·1	20·7	17	19·2	9	76
50·8	9·13	39·6	54·3	19·3	21	21·9	7	83
50·2	9·59	39·8	55·1	21·7	20	18·5	5	96

II. On Bars as Cast.

Composition.			Mechanical Properties.				
Copper.	Manganese	Zinc by difference.	Max. Stress Kilos. per sq. m.m.	Elastic Limit Kilos. per sq. m.m.	Elongation per cent.	Frémont Drop Test, Kilogrammetres.	Hardness Brinell.
			First Type.				
60·0	0·0	40·0	31·9	8·1	47	12	50
60·1	0·3	39·6	34·4	8·9	48	13	54
59·4	0·8	39·8	34·9	8·9	49	13	54
59·7	1·9	38·4	35·5	9·8	49	12	56
60·3	3·0	36·7	34·2	11.8	45	11	57
60·8	4·7	35·5	38·6	13·5	37	8	64
59·6	6·2	34·2	35·5	13·1	18	7	83
			Second Type.				
70·4	0·	29·6	20·0	5·7	68	11	32·0
70·6	0·4	30·0	20·3	4·7	57	11	32·8
70·3	0·9	29·0	19·7	6·5	45	11	36·5
69·7	2·1	28·2	20·6	5·5	47	11	38·0
70·8	2·9	26·3	20·3	7·4	34	11	38·0
70·5	4·2	25·3	23·7	12·7	44	9	43·0
68·9	6·1	25·0	19·6	10·1	17	10	50·0
70·2	9·3	20·5	30·5	12·9	32	9	54·0

inequalities of cross-section and sharp corners. A remedy naturally lies in lessening the resistance to contraction, and here three methods may be followed :—either the walls of the mould are made so weak that they are broken by the contraction of the iron; or immediately on solidification the opposing parts of the mould are removed; or the casting may be chilled at these points by the application of water, ice cold iron, etc. Therefore the accessibility of such points must be considered in the formation of the mould, and the mould boxes must be correspondingly constructed.

Pipe Founding.—Probably owing to its somewhat specialised character pipe founding does not receive much attention from the technical press; however, we notice in a late issue of the *Giesserei Zeitung*, an article by Mr. Fritz Häring dealing very generally with this subject. The preparation of moulds and cores is indicated, the value of casting large pipes in a vertical position and small ones at an inclination of 40 or 50 degrees is given. Large pipes which are blacked previous to drying should have the blacking poured over the surface of the mould, the surplus being collected at the bottom, sieved and used again. The blacking used consists of 75 per cent. graphite, 25 per cent. fine coke dust and two litres of molasses. Drying is quickly effected by means of a gentle blast which previous to ascending the mould is passed through a coke fire.

General Metallurgy.

*Researches on Copper Alloys.**—Brasses containing manganese are structurally very similar to ordinary brasses, thus an alloy containing 54 per cent. copper, 40 per cent. zinc, and six per cent. manganese had sensibly the same structure as one containing 54 per cent. copper and 46 per cent. zinc. Manganese in alloys plays a dual rôle: (1) by acting as a deoxidiser, and (2) by conferring special properties to the

* Continued from p. 798 of last issue (M. Guillet: *Revue de Métallurgie*).

I. On Bars as Cast.

Composition.			Mechanical Properties.				
Copper.	Zinc by difference.	Aluminium.	Max. Stress Kilos. per sq. m.m.	Elastic Limit Kilos. per sq. m.m.	Elongation per cent.	Frémont Drop Test, Kilogrammetres.	Hardness Brinell.
			First Type.				
60·0	40·0	0·0	31·9	8·1	47·0	12	50
59·6	40·1	0·3	32·3	9·9	51·5	19	51
59·9	40·3	0·8	30·9	9·5	45·0	14	52
59·6	38·5	2·9	46·0	11·8	14·0	9	101
60·4	55·9	4·7	44·1	17·8	2·0	5	148
			Second Type.				
70·0	29.6	0·0	13·7	5·7	50·0	11	32
69·0	29·9	0·4	20·3	4·7	59·0	13	33·8
70·0	28·8	0·9	22·7	6·6	67·0	13	33·8
70·3	26·4	3·1	33·9	13·5	50·0	7	65·0
70·1	24·7	5·2	50·8	7·4	11	5	107·0

II. On Bars Rolled, Drawn, Annealed.

Composition.			Mechanical Properties.				
Copper.	Zinc.	Aluminium.	Max. Stress, Kilos. per sq. m.m.	Elastic Limit, Kilos. per sq. m.m.	Elongation, per cent.	Frémont Drop Test, Kilogrammetres.	Hardness Brinell.
61·4	38·4	0·7	35·2	10·1	45·0	17	52
60·3	38·2	1·1	38·1	11·3	36·0	16	59
61·0	37·7	1·4	36·7	12·3	43·5	16	65
59·9	37·9	2·0	39·1	18·1	17·0	9	123
59·8	37·2	2·7	44·5	17·7	16·0	7	123
60·0	36·4	3·9	48·1	18·3	13·0	5	148

alloy. The latter is exemplified in the following tests.

From these tests on differing alloys in various conditions the influence of manganese may be summarised as:—(1) sensibly increasing elastic limit and maximum stress; (2) increasing ductility up to a certain content, which is in turn followed by a decrease; (3) increasing fragility from 4 per cent. upwards; and (4) a slow but perceptible increase in hardness with an ascending manganese content.

Aluminium Brasses. From micrographic studies the conclusion is reached that 1 per cent. aluminium is structurally equal to 3·5 per cent. zinc. Thus an alloy of copper 70 per cent., aluminium 6 per cent. and zinc 24 per cent. possesses the same structure as an alloy containing copper 55 per cent. and zinc 45 per cent. The influence of aluminium on the mechanical properties is shown in the preceding tables.

From these results we gather that an ascending content of aluminium raises the elastic limit and maximum stress slowly; it increases then diminishes ductility, and when present in low quantities increases very clearly the resistance to shock.

Quenching of Bronzes. A series of copper-tin alloys have been quenched from various temperatures and the influence of quenching studied by means of tensile tests. From the results of these tests the following conclusions are reached:

(1) Bronzes containing more than 92 per cent. copper have their breaking load increased a little by quenching from low temperatures, *i.e.*, from 400° to 600° C. Elongations undergo analogous variations. (2) Bronzes containing less than 92 per cent. copper when quenched from temperatures exceeding 500° C., result in a marked increase of breaking load and elongation. The maximum of the breaking load is attained, irrespective of composition, at a temperature of about 600° C. The maximum elongation, however, appears to be a function of temperature and composition. Thus a quenching temperature of 800° C. yields the highest elongation for a bronze containing 90 per cent. copper and 9 per cent. tin, whilst with bronze of 79 per cent. copper and 21 per cent. tin, this point is reached at a quenching temperature of 600° C. The difference in breaking load of the bronze as cast and quenched from its most suitable temperature is greater as the content of copper in the bronze is lower.

Copper, Tin, and Oxygen. Mr. O. Bauer contributes an article to *Giesserei Zeitung* on the influence of oxygen on copper and bronze. Copper is taken first, and the earlier work of Professor Heyn in this direction is indicated. The affinity between copper and oxygen at high temperatures is familiar, and the resultant oxide is to some extent soluble in copper. In Fig. 1 the influence of an ascending oxide content on the beginning of solidification is shown, A corresponding to pure copper, 1084° C. the

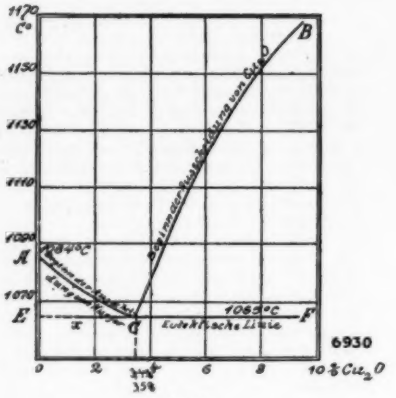


FIG. 1.

line B denoting the separation of Cu_2O. the melting point of pure oxide not being reached. With ascending oxide content the beginning of solidification falls along the line A-C. At C, 1065° C. a fixed combination is reached and the mother liquor solidifies as an eutectic containing 3·4 or 3·5 per cent. Cu_2O. With higher oxide content the beginning of solidification follows the line C-B.

Therefore, when cold a copper containing less than 3·4 per cent. Cu_2O will structurally consist of two components, pure copper and the eutectic of copper and copper oxide. Fig. 2 reproduces such a structure where (*a*) represents pure copper, and (*b*) the eutectic. At 3·4 per cent. Cu_2O the whole of the structure consists of (*b*) whilst exceeding 3·4 per cent. free oxide appears in a ground work of eutectic as shown in Fig. 3.

FIG. 2.—COPPER, TIN, AND OXYGEN.

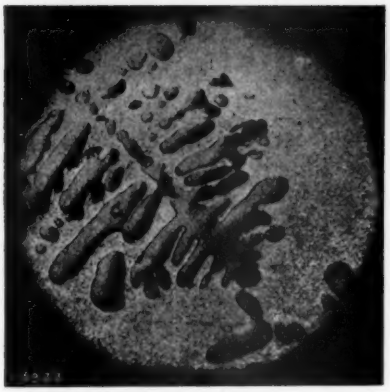


FIG. 3.—COPPER, TIN, AND OXYGEN.

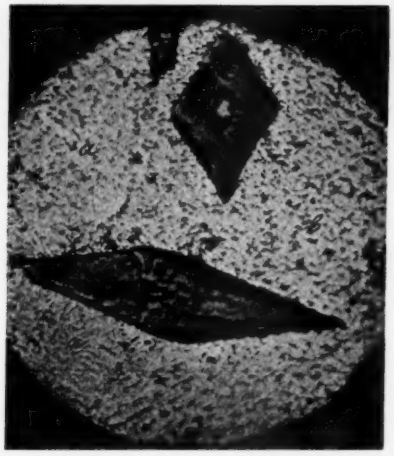


FIG. 4.—COPPER, TIN, AND OXYGEN

Here (*b*) represents the eutectic and (*c*) the free oxide. The range of copper oxygen alloys may, therefore, be considered as

A. Oxygen free copper;
B. Eutectic mixture of *a* and *c*; and
C. Crystals of copper oxide.

Copper and oxygen are in the foregoing clearly demonstrated; unfortunately the same remark is not applicable to the author's elucidation of copper, tin, and oxygen. Turning to the experimental part of the paper the following constituents were melted and allowed to slowly cool: 91·2 per cent. Cu; 4·4 per cent. Cu_2O, and 4·4 per cent. Sn. The solidified mass permitted of division into three layers. The structure of the upper one was characteristic of copper and the oxide eutectic, see Fig. 2.

Embedded in the eutectic were crystals of a gray-blue colour, as shown in Fig. 4, which represents an etched surface. The lower layer presented the usual characteristics of a copper-tin alloy, the presence of copper oxide not being indicated. The central layer was intermediate between the upper and the lower one. Apparently then the presence of oxide has broadly divided the alloy into two layers, the upper one presenting none of the characteristics of bronze but showing a structure of copper, copper oxide and crystals of the copper-tin alloy, the lower layer showing all the characteristics of an oxygen free bronze.

(*To be continued.*)

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Sewer Ventilation at Winnipeg. The report by Mr. Allen Hazen on the sewers of Winnipeg, is especially noteworthy. Mr. Hazen recommends that they be ventilated through the house soil-pipes, a proposal which even at this day will doubtless shock some who pose as sanitary experts. *Engineering News*, 9th March, 1905.

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TRADE NOTES AND PUBLICATIONS.

Steam Gauge and Syphon.

J. Hopkinson & Co., Ltd., Huddersfield.—List No. 340, dealing with a new and novel form of steam gauge and syphon, designed to secure a firm support for the steam gauge, quite independent of the syphon. The latter is in the form of a copper coil, which can be easily detached and blown through without disturbing the gauge, which is a great disadvantage. This is one of the special features of the new arrangement, as it permits of the gauge being tested by a separate pump without dismounting the gauge. The support for the gauge being independent of the coil, it follows that the weight of the gauge is a matter of indifference, and advantage is taken of this to use a sector-shaped gauge whose working parts are more mechanical than those in the circular gauge, The dial is marked on opal, and is illuminated. The combination of gauge and syphon coil can be swung round to any angle, which makes it possible to read a number of gauges simultaneously from one position. It remains to be mentioned that the swivel arm attached to the back of the gauge is effectively insulated by a washer of special material, with the result that the gauge and its tube are kept cooler. The combination of gauge, syphon, and electric lamp make an extremely handsome fitting.

Electrical Accessories.

Davies, Kent & Steward, Ltd., 17, *Berners Street, W.*—Catalogue of electrical accessories.

Rivets, Bolts, Nuts, etc.

T. D. Robinson & Co., Ltd., Derby.—Price list of rivets, bolts, and nuts, washers, etc.

Induced Draught for Boilers.

Matthews & Yates, Ltd., Cyclone Works, Swinton.—Pamphlet relating to induced draught for steam boilers.

Enamel Paints.

British Fibro-Cement Syndicate, Norfolk House, Laurence Pountney Hill, E.C. — Catalogue of Marcoid enamel paints. This is an enamel paint which withstands the action of cement plaster. It is turned out for either gloss or flat finish. Marcoid submarine paints, graphite, and bridge paints are also dealt with in the catalogue.

Arch Plate.

The Wellman-Seaver-Morgan Company, Cleveland, Ohio.—Descriptive pamphlet of the Johnson Patent Arch Plate, a device to facilitate the work of repairing and rebuilding furnace door arches.

An unfortunate collapse of the pumping plant at Roall Waterworks, which occurred recently, afforded an opportunity of demonstrating the advantages possessed in an emergency by the PULSOMETER PUMP. Although the pumping station is five miles from the nearest town, the Borough Engineer, Mr. John E. Pickard, was able to get a complete temporary set of pumps at work in under fifty hours, thus averting a serious water famine in the district. A large Pulsometer set was fixed a day or two later, and this sufficiently maintained the water supply for over three weeks, during the time the broken pumps were undergoing repairs.

From MESSRS BAXENDALE & Co., of Manchester, we have received a sample of their new Patent "Thikflex" Cord Grip Lampholder, which has one or two new features. The case is in two parts only, which screw together and interlock the cord grip, china interior, and terminals with each other, so that it is impossible for them to be twisted or become detached. The interior, which is in two parts, is of best English china, and is so constructed that, when put together, the terminals, which are not permanently fixed to the china, are held quite firmly in position, and are entirely insulated from one another and from the case itself, no metal being exposed beyond the plungers themselves. The terminals, being loose, are much more easily wired. The cord grips are very effective. When the holder is wired and made up, the cord grip cannot possibly be twisted, and retains such a firm hold on the flexible that all strain is taken off the connections. The size of the cord grip allows a large variation in adjustment for different thicknesses of flexibles, and we can at all times supply cord grips drilled to suit any flexible of unusual diameters.

A sample battery, specially arranged for the electric ignition of gas engines, has been sent us by the EDISON MANUFACTURING COMPANY, LTD., 25, Clerkenwell Road, E.C. It is of a type formerly known as the Edison-Lalande, in which a copper oxide plate contained by two grooved copper supports forms the negative element, and two zinc plates the positive. The whole is suspended from the cover in an electrolyte of caustic soda, on which is floated a layer of oil to prevent evaporation and creeping. The characteristics of this type of cell, which render it so eminently suited for electric ignition, are the very steady current, the absence of local action, long life, and the simplicity of construction. The Edison Primary Battery is made in

three sizes for stationary work, viz.: "BB," 100 ampere-hour, "Q," 150 ampere hour; and "RR," 300 ampere hour—all of which are furnished with porcelain jars, so they will stand considerable hard usage without being damaged. It is customary to use four to five RR or AA cells, five to six Q or V cells, and six to seven Z or BB cells for gas engine work. The advantage of using the larger sizes is that it is possible to use a smaller number of cells on each engine, and also the life of the battery is much longer than when the smaller cells are used. The advantage of the smaller cells is that they are lighter in weight and occupy less space, and consequently are better adapted for portable work.

THE KENNICOTT WATER SOFTENING COMPANY, 29, Great St. Helens, London, E.C., notify us that their American office have just sold to the Carnegie Steel Company the largest continuous water softener that has ever been erected. The machine, which has a capacity of 150,000 gallons per hour, will be 60 ft. high and 50 ft. diameter. The water to be treated is not only quite hard, but is full of free sulphuric acid, caused by the sludge of the coke ovens and rolling mills being drained into the river at this point.

MESSRS. MACKIES, LTD., Caversham Road, Reading, send us particulars of a pulley of new design, now being placed on the market by them. It is built up of an iron boss, on to which are fitted the arms, which are of ordinary steel bars. The arms are bolted to a band of rolled T-iron or steel, the latter giving great strength to the pulley. As it is set true in the lathe, it ensures the pulley running well. The arms are readily removed, and any one can be taken out and replaced without interfering with the other parts.

THE HUCKNALL TORKARD COLLIERY COMPANY, LTD., have placed an order with Mr. P. J. Mitchell, 52, Queen Victoria Street, E.C., for a 130 kw. turbo-generating plant for use in connection with Professor Rateau's Patent Exhaust Utilization System, the accumulating mass being, in this case, formed of old rails enclosed in a boiler shell. This plant will be the first of its kind to be laid down in a British colliery. The Steel Company of Scotland have also placed a similar contract for a complete installation of Rateau exhaust accumulator regenerators, together with necessary turbo-generating plant. The plant will regenerate steam from one cogging mill engine, one finishing mill engine, and four large steam hammers, and will eventually, when the second unit is installed, provide the works with 1,300 e.h.p., without any increase of present fuel costs. The first unit is now on order, together with condensing plant large enough for the complete installation. This will be the first plant on Professor Rateau's system to be erected in the United Kingdom.

THE HARRIS PATENT FEED WATER FILTER, LTD., have removed their London office and laboratory to 82, Victoria Street, Westminster, S.W.

The unique design of coal-handling plant for which the Lea Bridge District Gas Company have placed the order with MESSRS. GRAHAM, MORTON & CO., LTD., Leeds, is to be constructed to the plans of Mr. F. W. Cross, A.M.Inst.C.E. The plant is very complete; it is, moreover, simple in conception, and promises to be effective in operation. The drawing before us shows that a hydraulic wagon tipper, capable of raising the ordinary standard railroad wagon to an angle of 46 degrees, is provided. The wagon tipper is suitable for a working pressure of about 700 lb. per sq. in. This hopper is fitted with a flat-bar screen on the top, so that all the large coal can be broken before passage to the elevator. The underside is arranged to accommodate a jigger feeder for regulating the supply of coal to the elevator. The latest is of the cased-in type; the dimensions are 18 in. and 45 ft. between centres. It is provided with a breeches shoot at the head, with flap door, and levers for operating the same. The band conveyor is of the 16 in. standard type, 106 ft. between centres, and capable of conveying 25 tons of coal per hour, at a normal speed of 200 ft. per minute. A standard travelling throw-off carriage, for delivering the coal on either side of the conveyor, is to run the entire length of the stores. The friction gear is so arranged as to admit of the carriage running in either direction as required.

J. H. HOLMES & CO., Portland Road, Newcastle-on-Tyne. Fourth and revised edition of the catalogue of the Lundell and Castle Motors of which this firm are the sole patent owners. This catalogue contains full particulars of the round two-pole motor and of different ventilation outfits. A description is also included of the Holmes-Clatworthy Patent System for driving newspaper printing machines, etc. This consists of two motors, main and auxiliary, specially arranged and connected with suitable controlling switches. The whole of the operating of starting "inching" round, speed regulating and stopping are effected by a single handle or wheel.

We have also received up-to-date lists of installations which have been carried out by this firm on steamships, railways and dockyards, newspapers, textile mills, &c. Also a catalogue of recording instruments, which latter will run for a fortnight without re-winding or re-inking.